Vol. 15, No. 8 August, 1959

LUBRICATION ENGINEERING

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

Lubrication of Small Mechanisms

(see page 328)

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

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Volume 15, No. 8
August, 1959

Lubrication Engineering

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

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Book Published On Plant Maintenance And Engineering

The tenth volume in the annual series, "Techniques of Plant Maintenance and Engineering," has been published by Clapp and Poliak, Inc., 341 Madison Ave., New York 17, N. Y. It is priced at $10 postpaid. It contains all papers read at the 1959 Plant Maintenance and Engineering Conference held in Cleveland last January.

One of the major features of the book is the vast number of practical situations it covers. Included are answers to 1,056 questions submitted by engineers attending the conference. More than 70 charts, graphs and diagrams are reproduced.

Coolant Costs Cut

By switching to a specialized cutting coolant, a manufacturer of steel products has reportedly increased saw blade life, improved edge finish and reduced coolant requirements by 90 per cent.

Many types of metals are sawed by this manufacturer, including round stock, bar stock, angle stock and flat stock in a variety of sizes, thicknesses and hardnesses. The coolant formerly used for this cutting job had to be applied full strength and did not give adequate blade life.

This problem led the company to investigate coolants that were specially made for problem applications. The coolant chosen was Keystone 106. The manufacturer says that this specialized machining coolant costs less than the conventional coolant formerly used and is applied in diluted form—ten parts of water to one part of the coolant.

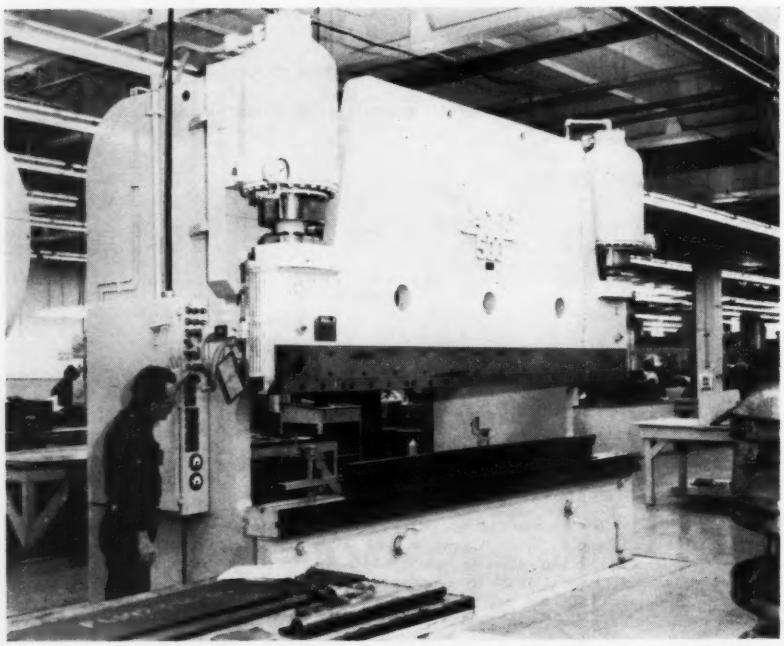
Because cooling is more efficient with the new coolant than with the former coolant, cutting blade life has been extended, output has been accelerated and metal edge finish has been improved.

Chemical Society To Hold Symposium

The American Chemical Society is planning a symposium on Lubrication Under Extreme Conditions to be held during their April, 1960 meetings in Cleveland. This symposium will be sponsored by the Division of Petroleum Chemistry and is scheduled during the Petroleum Division meetings from April 11 to 14. W. A. Zisman, of the Naval Research Laboratory, Washington, D. C., has been named chairman.

Load Ratings For Bearings Standardized

For the first time, an American Standard method of evaluating load ratings for ball and roller bearings has been established, providing a uniform capacity rating system for bearings made by all manufacturers. Published by the American Standards Association, the new American Standard B3.11-1959 is truly international since it is identical in all major technical respects with ISO Recommendation 76 of the International Organization for Standardization covering static testing of bearings and the latest draft proposal covering dynamic testing. (*Cont. on next page*)



Press Brake Specially Designed For Hot Forming

A hydraulic press specially designed for hot forming is the unusual, new research tool being used at Boeing Airplane Company, Seattle, for investigation work on titanium and other high temperature metals. A series of push-buttons automatically control the rate of advance of the ram. The ram dwells for a predetermined interval above the material being hot-tool heated up to 1200F and then descends into the metal at a preselected rate. Adjustable combinations of forming rates and dwell and soak intervals permit automatic cycling for a variety of metals and requirements. The 500-ton press brake was manufactured by Pacific Industrial Manufacturing Company, 848 49th Ave., Oakland, California.

LUBRICATION IN THE NEWS

(*Cont.*)

The standard establishes uniform test procedures and statistical methods for determining load-carrying capacity and expected fatigue life of both ball and roller bearings. It covers dynamic as well as static capacity of radial and thrust type bearings and contains definitions of bearing life, basic load rating, equivalent load, basic static rating, and static equivalent load. It also gives formulae for calculating these for different types and sizes of bearings.

Based primarily on experimental work in Europe by A. Palmgren, G. Lundberg, B. Anderson, and E. Bratt, standards were written in this field by the Anti-Friction Bearing Manufacturers' Association. These standards were revised and expanded during the past ten years, and under ASA Sectional Committee B3 on Ball and Roller Bearings, they were combined and approved as American Standards under ASA procedures.

An American Standard is voluntary. To be approved by ASA, it must be accepted by a consensus of national groups substantially concerned with its scope and provisions. The new bearings standard was approved by associations of bearing producers as well as users, by engineering societies, and by several government agencies.

Writing in the current issue of the Magazine of Standards, published by ASA, Gunnar Palmgren, vice-president of SKF Industries, Inc., and chairman of Subcommittee 7 on load ratings of Sectional Committee B3, commented, "The load-carrying capacity and expected fatigue life of such bearings are matters of considerable complication. For lack of something better, bearing manufacturers originally developed and applied their own methods of evaluation, using empirical formulae based on limited testing and general experience. As a result, there sometimes were marked differences among the capacities claimed by different companies for the same type and size bearing, causing confusion among bearing users. This standard can be used by bearing manufacturers and users alike, and should be the desired uniform basis for bearing ratings."

American Standard Method of Evaluating Load Ratings for Ball and Roller Bearings, B3.11-1959, is available at $1.75 a copy from the American Standards Association, Dept PR 81, 70 East 45th Street, New York 17, New York.

PRODUCT LITERATURE

BROCHURE GIVES DETAILS ON WEIGHING SYSTEM

A new eight-page, two-color brochure describes the 5000 lb capacity weighing cells as well as the instrumentation which can be used with them. Five basic types of cells are pictured and diagrammed. This is another in the "Plan-It-Yourself" catalog series being published by this hydraulic weighing system manufacturer. Component selection instruction and a summary price sheet are part of the bulletin. Copies of Bulletin 591 may be obtained from the A. H. Emery Co., Pine St., New Canaan, Conn.

BEARING DATA GIVEN

Bulletin 110 provides information about the many types and sizes of deep-groove ball bearings. Because of their versatility in carrying loads, these deep-groove, Conrad-type bearings are used in a variety of applications. Standard width deep-groove bearings are made in extra light, light, medium and heavy series. They may be open, equipped with shields or contact seals, and are offered with or without snap ring. Deep-groove bearings of cartridge design or with felt seals are also available. Dimensions, loads and other application data for all these deep-groove bearings are included in the 12-page bulletin. Copies may be obtained by writing Advertising Dept., Hoover Ball and Bearing Co., 5400 So. State Rd., Ann Arbor, Mich.

CATALOG SHOWS VALVES AND ACCESSORIES

Waterman Engineering Co., 725 Custer Ave., Evanston, Ill., is offering a new 12-page catalog of filters, check valves, unloading valves, relief valves, and fuses for hydraulic power systems. The catalog is a companion piece to the company's other catalogs on flow regulators and solenoid valves. Filters shown are rates for hydraulic pressures up to 5000 psi, for filtration as fine as ten microns. The valve sections of the catalog show equipment rated up to 3000 psi, including several designs reportedly never before cataloged. Complete, well-arranged information is given, including dimensions and pressure drop charts, to enable the designer to make his own filter and valve selection in most cases. Ask for Catalog No. 3000.

FOLDER GIVES DETAILS ON LUBRICANTS

An illustrated folder providing detailed information on D-A Universal Lubricants has been published by the manufacturer of heavy-duty lubricants for the construction industry. The 2-color folder describes the reasons for the creation of low-activity heavy duty gear lubricants, and the advantages of using the D-A Universal Lubricants. Unretouched comparative photographs show the relative lack of oxidation encountered in the products. Advantages claimed for the lubricants include elimination of sludge, moisture and corrosion; high, natural, stable viscosity index; reduced leakage and consumption; retention of additives and elimination of foaming. The folder also discusses the use of straight mineral oil gear lubricants in applications where gear designs do not require the additives used in the specialized lubricants. The folder can be obtained on request by writing to the D-A Lubricant Company, Inc., 1331 W. 29th St., Indianapolis 23, Ind., or through local representatives.

BULLETIN DESCRIBES MOLDED CUPS

A bulletin describing the latest types of molded cups for pump pistons, hydraulic service and for pneumatic equipment has recently been published. The new booklet, which updates the company's previous literature on this subject, is designated Bulletin AD-145, and it details the construction, recommended service and available sizes of rubber and synthetic rubber, leather, reinforced synthetic rubber, metal bonded and metal reinforced and homogeneous cups. The bulletin also contains tables illustrating the most popular cups for recommended services on a wide variety of general applications. A section is devoted to the conversion of pistons designed for operation with hydraulic ring packings to pistons designed for use with pump cups. This includes pistons for tapered and straight rods. Copies of Bulletin AD-145 may be obtained by writing The Garlock Packing Co., 436 Main St., Palmyra, N. Y.

COOLANT SYSTEMS BULLETIN ANNOUNCED

A four-page bulletin describing a number of mist coolant systems and units is offered by the Trico Fuse Mfg. Co. The bulletin gives detailed specifications for single as well as units for supplying multiple installations. It pictures five models and lists proper application information. For a copy of this bulletin, write Trico Fuse Mfg. Co., Milwaukee 12, Wisconsin.

NEW PRODUCTS

NEW ADDITIVE OFFERS ECONOMY

Acheson Colloids Co., a division of Acheson Industries, Inc., Port Huron, Mich., announces a new molybdenum disulfide additive for greases and heavy oils. The new MoS_2 dispersion, designated 'dag' 208 by the manufacturer, reportedly provides substantially greater coverage than the finest commercially available molybdenum disulfide powder at no increase in solids content, extending the range of applications to even closer-tol-

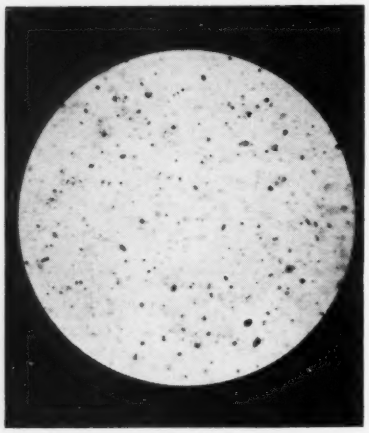


Fig. A

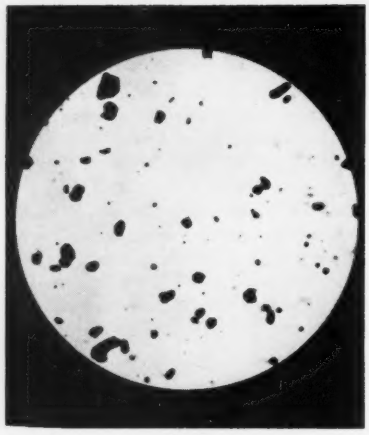


Fig. B

erance mechanisms. Photomicrograph comparison (enlarged) of 'dag' 208 (Fig. A) and MoS_2 powder (Fig. B) shows that the predominantly finer particles in the pre-wetted dispersion provide 80 per cent greater hiding power. The ultimate result is more coverage per dollar. Other advantages listed for the new dispersion include consistent uniformity. The ease with which this additive can be handled, measured and blended provides additional savings in time and labor.

T-BOLT CLAMPS GOOD FOR EXTREME CONDITIONS

A new low-cost line of T-bolt clamps for critical applications on hose and duct connections are available. According to the manufacturer, the clamp is especially recommended for hose and duct connections subjected to high internal pressures, severe vibration, corrosive atmospheres, or high temperatures. The manufacturer explains that the flexible stainless steel band exerts an extreme radial clamping pressure, uniformly around the circumference, to prevent bulges, bends, or distortion of the clamp. This assures perfect sealing with extreme conditions. The T-bolt clamp is made with a stainless steel strip and cadmium-plated T-bolts, trunnions and nuts. For extreme conditions, units are available with all components of stainless. For further information contact Voss Engineering Co., 2193 W. 26 St., Cleveland 13, O.

AEROSOL CANS HELP LUBRICATE

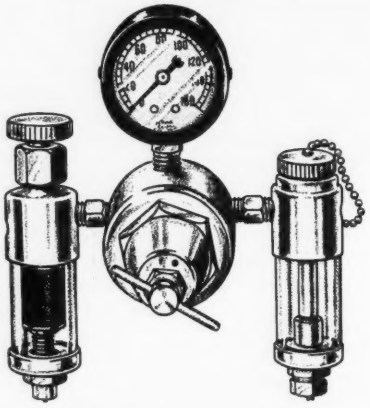
Reportedly on the market is a line of aerosol products for industry. Described as the key to push-button maintenance, the new line consists of 47 maintenance and production aids in self-spraying containers. Aerosol cans save on time and labor costs, according to the manufacturer, always ready for use anywhere and requiring little or no preparation or clean-up. In addition, spray application gives improved product performance. These aerosol cans include color code enamels and marking paints, standard equipment finishes, special lubricants, protective coatings, and de-greasers. It reportedly covers virtually every self-spraying product used in industry, from silicone mold release to blue layout fluid. Also featured is the Jet-Pak sprayer, a re-use self-powered spray gun that sprays liquid at the touch of a button. Sold through industrial distributors, aircraft distributors, and mill supply houses, this line is aimed at utilities, transportation and defense establishments and general industry. A free handbook of "Aerosols for Industry" is available from Industrial Supply Division, Sprayon Products, Inc., 2075 E. 65 St., Cleveland 3, Ohio.

DIE-CASTING LUBRICANT ON MARKET

The Die Casting "ID" Corp., 4902 Ledge Ave., North Hollywood, Cal., announces its new industrial lubricant, "ID" Plunger Lube, for die-casting plunger lubrication under extreme temperature conditions. This dark, bronze colored lubricant contains electric furnace graphite and holds other micro-fine metallic combinations in suspension for evenly distributed lubrication. It is compounded in three consistencies—light, medium and heavy. It flows at room temperature and therefore does not require a high pressure system for automatic lubrication. It will not thin out when applied to hot plunger tips, nor will it allow by-passing of fluid into the casting runners with its resulting objectionable gas porosity. Information and prices on this and other die-casting lubricants are available by writing.

AIR LINE FILTER AVAILABLE

The Oil-Rite Corp. has developed an air line filter-oiler-regulator. This compact combination filters air, removes moisture, supplies an oil mist, and regulates air pressure to a desired value. The air filter, capable of handling capacities up to 7 cfm, is equipped with a 40 micron filter element which can easily be cleaned or replaced. Condensate can be drained from the transparent reservoir through a small valve on the bottom. A needle valve shut-off is provided on top of the filter. The oil delivery can be regulated on the bottom of the oiler.



The top filler cap makes replenishing the oil an easy matter and the transparent reservoir will tell at a glance when refilling is needed. The regulator will reduce air pressure to any selected valve and automatically retains this secondary pressure. The design is compact with adjusting screw of ample diameter and extremely simple and easily removed valve seat. The flow is unrestricted with a minimum pressure drop. All components, filter, regulator, oiler, can be purchased separately if desired.

(*Cont. on p. 310*)

It's a multipurpose grease . . . but *how* multipurpose?

You can't "feel" the answer. Any "multipurpose" grease you buy is a compromise. Lubrication engineers say it *can't possibly be* the best lubricant both for high speeds and low loads . . . and for low speeds and heavy loads. It's *got to be* somewhere in between, so that it can do both jobs fairly well.

What you should do is decide on *which* multipurpose grease is best for you. This is a decision for an expert team—you and your Sun representative—because you have to consider many variables.

We feel, justifiably, that one of Sun's Prestige Multipurpose Greases is designed with that wide range of applications you're looking for. They last longer under pressure, water, heat, and other abuses. They bear investigation. To start enjoying the real economy of quality, call that Sun man today—or write direct to SUN OIL COMPANY, *Philadelphia 3, Pa. Dept. LE-8. In Canada: Sun Oil Company Limited, Toronto and Montreal.*

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MAKERS OF FAMOUS CUSTOM-BLENDED BLUE SUNOCO GASOLINES

SIR HENRY BESSEMER *concentrated on steel metallurgy when England needed cannons for the Crimean War. Steel was then being made from wrought iron by the slow, costly crucible method. He sought to produce it faster by blowing air through molten pig iron. His first attempt, in 1854, succeeded.*

But Bessemer's process required Swedish iron and could produce only high carbon steel. With English irons, it failed completely. For years, Bessemer tried to produce mild steel. The final solution came when manganese was added in the form of spiegeleisen, opening the door to the modern age of steel.

Great Names in Steel Making

IN the record of Henry Bessemer's achievement, two facts stand out. His research was prompted by a wartime need, and his process was not perfected until freed from its dependence on imported iron.

Both facts have an interesting parallel in the development of an all-American lubricant to replace imported palm oil.

The search for a satisfactory domestic roll oil began during World War II, when the steel industry woke to its dangerous dependence on palm oil, brought across submarine-infested seas. Success was reached midway in the Korean War, when Ironsides announced the perfecting of Palmoshield, the "palm tree that grows in Ohio."

In use in most of the rolling mills of North America, Palmoshield has demonstrated that it has every desirable characteristic of palm oil, plus greater uniformity and the immeasurable advantage of being produced entirely from domestic materials.

Ironsides engineers are accustomed to solving lubrication problems. To achieve a satisfactory roller bearing "Shield", for example, it was necessary to develop a lubricant that was pumpable, water-repellent, able to support high speeds and extreme pressures, yet free-running so as to minimize the costly power consumption of modern rolling mills.

Working in close cooperation with mill superintendents, lubrication engineers and rollers, such Ironsides "Shield" lubricants are compounded to each user's individual preferences and operating requirements. They can be supplied in any quantity, from pails to tank cars.

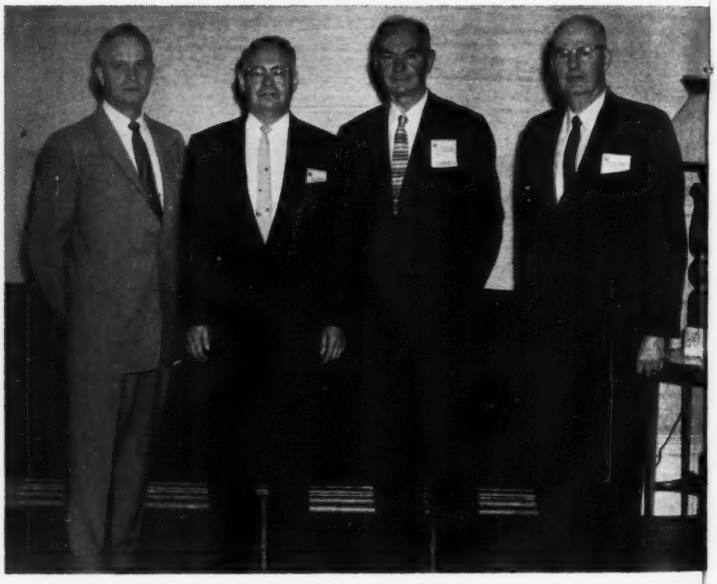
Do you have a problem — or an interest in improving lubrication performance? You need only write, or phone for an Ironsides research engineer. Address The Ironsides Company, Columbus 16, Ohio.

JOSEPH MARGULIES.

(Left) The students concentrate on their instructor and their notes. The course was especially helpful to men in small plants or other operations not large enough to justify employment of a lubrication engineer. They were supplied with basic information to draw on when recommending lubrication practices.

ONE-DAY LUBRICATION COURSE SUCCESS

FOR NORTHERN CALIFORNIA SECTION



(Right) The success of the one-day Course on Practical Lubrication sponsored by the Northern California Section was due largely to the instructors; (l. to r.) Ora Wollam, Shell Oil Co., John Morris, Western Gear Corp., Otto Neumer, SKF Industries, Inc., Watson Beggs, Alemite Company of Northern California and (not appearing in photograph) Fred Hanly, California Research Corp. Discussion was encouraged by the instructors at the end of each session.

(Left) The instructors and students take a lunch break to eat and discuss the events of the morning. After lunch, the men went back to class. The course, which was designed to be of assistance to the operator of equipment and the foreman who supervises him, was also of great value to the general foreman who needs a basic knowledge of lubrication to aid in the supervision of maintenance.

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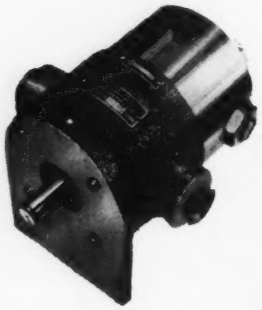
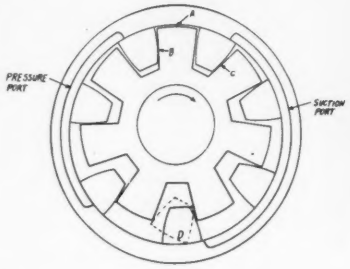
NEW PRODUCTS

(*Cont. from p. 304*)

SLIPPER TYPE PUMP GIVES QUIET OPERATION

A new Kingsbury Slipper Type hydraulic pump has just been announced by Mechanisms, Inc., 118 E. 2nd St., Uhrichsville, Ohio. According to the manufacturer, Model 1372 is designed for material handling applications from ½ to 2 ton, where pressures to 1500 psi are common and capacities of 1 to 2 gpm usually required. The manufacturer points out that the thrust bearing principle is utilized in the new pump slippers which support the load on a hydrodynamic oil film—giving minimum friction, quiet operation, and maximum dependability. Slippers exactly fit the bore contour instead of giving just the line contact normally obtained with vanes.





In pump diagram above, liberal clearance at *A* eliminates trapping—assures quiet operation. Sealing occurs at points *B* and *C* as centrifugal force and pressure hold slippers out and forward against rotor. In position *D* pressure holds slipper against rotor and the angle of application of the driving force, as well as the pressure, assures hydrodynamic lubrication.

HEAVY-DUTY LUBRICANT AVAILABLE FOR GEARS

Type 223X, a heavy-duty gear lubricant available in SAE 90 and 140 grades, has been announced. Reportedly made from the highest quality solvent-refined paraffin base stock plus a special formulation of EP additives which include Type M-55, the new Type 223X is designed to provide satisfactory lubrication wherever the following problems are encountered:

a. gear cases operating at excessive frictional temperatures;
b. unsatisfactory wear life; and
c. gears loaded beyond the recommendations of the gear manufacturer.

The new gear lubricant has equally good load carrying ability through the entire range from the lowest to the highest sliding velocities and it is most effective in reducing wear. Type 223X has a viscosity index of 100. Its flash point is 390F and its fire point is 420F. Its specific weight is 7.5 pounds per gallon; has a pour point at 0F; contains a foam depressant and is corrosion and oxidation inhibited. For complete details write The Alpha-Molykote Corp., 65 Harvard Ave., Stamford, Conn.

PERSONALS

Robert A. Kraus

Robert A. Kraus, Republic Steel Corp., Chicago, has been appointed manager of a construction project involving Republic's $55 million dollar expansion of hot rolling facilities for flat roll products at Warren, Ohio.

A. J. Weith has been named director of petrochemicals and mining chemicals research for the Organic Chemicals Div., American Cyanamid Co. Weith has been with Cyanamid since 1947 when he joined the company as a research chemist.

The appointment of Raymond C. Zurbrigg, E. F. Houghton & Co., as lubrication engineer has been announced. Zurbrigg's appointment continues the expansion of Houghton's research program in the development and application of specialty lubricants.

National O-Rings are precision made, uniform commercial rings available throughout the United States—promptly! Quality is superior; all ingredients are inspected before compounding and compounding is strictly controlled for maximum uniformity. Molding is done on modern equipment by veterans of 20 years in O-Ring manufacture. Every precaution is taken to insure that no O-Rings with cuts, scratches or mold defects are shipped.

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6th ANNUAL JOINT
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October 20, 21, 22, 1959
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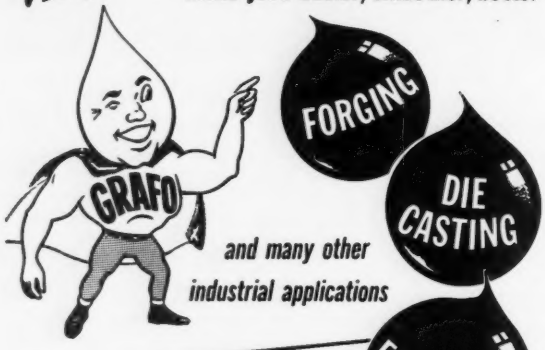

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TWELVE ASLE AUTHORS TO PRESENT PAPERS AT LUBRICATION CONFERENCE

Twelve important papers are scheduled to be presented by ASLE members at the 1959 ASLE-ASME Joint Lubrication Conference. This conference will be held at the Sheraton-McAlpin Hotel in New York City, October 20, 21, 22. Sponsored jointly by the American Society of Lubrication Engineers and the Lubrication Division of the American Society of Mechanical Engineers, this year's meeting is expected to be very well attended by members of both groups. Listed below are the papers to be presented by ASLE members.

"Transition Temperatures with Four Ball Machine"
by R. S. Fein

"Distribution of EP Film on Wear Surfaces"
by R. C. Wiquist, S. B. Twiss and E. H. Loeser

"A Comparison of Lubricants and Coatings for Cold Extruding Titanium"
by A. M. Sabroff and P. D. Frost

"The Effect of Root Lubrication on the Damping of Cantilever Beams"
by R. V. Klint and R. S. Owens

"The Influence of Silicon Additions on Friction and Wear of Nickel Alloys at Temperatures to 1000° F."
by D. H. Buckley and R. L. Jackson

"Evaluation of Gear Materials Scoring at 700° F."
by E. G. Jackson, C. F. Muench and E. H. Scott

"Meta-Linked Polyphenyl Ethers as High-Temperature Radiation-Resistant Lubricants"
by C. L. Mahoney, E. R. Barnum, W. W. Kerlin and K. J. Sax

"The Calculated Journal Bearing Performance of Polymer Thickened Lubricants"
by H. H. Horowitz and F. E. Steidler

"Gear Lubrication in Inert Gas Atmospheres"
by B. B. Baber, C. W. Lawler, H. R. Smith, G. A. Beane and P. M. Ku

"An Analytical Investigation of Visco-Elastic Effects in the Lubrication of Rolling Contact"
by R. A. Burton

"Sliding Characteristics of Metals at High Temperatures"
by M. B. Peterson, J. J. Florek and R. E. Lee

"A Research Program on the Investigation of Seal Materials for High Temperature Applications"
by R. H. Baskey

Preprints of the above papers will be available at the Conference for those attending. They will also be available at the ASLE National Office for mail-orders after October 15, 1959. Abstracts of these papers will appear in next month's issue of Lubrication Engineering.

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by A. F. Brewer*

INSURANCE VALUE

One can "lose sight of the forest for the trees" is a truism which too often can be applied to a casual attitude toward lubrication. To be sure, it is the little things that count, but when we pay too much attention to details, (and first cost is one of them) and overlook the insurance value of lubrication, we could be curtailing the useful life of our machinery and increasing its cost of maintenance.

Insurance value means just what it infers where lubrication is concerned: that the maximum of protection of the operating mechanisms will result. The builders of automatic lubrication devices have realized this need; the petroleum and organic chemists have worked together in their study of refinery procedures and additive compatibility; but unless the plant selects lubricants capable of functioning most dependably, much of what we hope we are paying for may be lost.

Insurance value is not something like a pot of gold at the end of a rainbow, it is a tangible actuality which can be measured directly in dollars and cents, as related to production. Unlike some other types of insurance this benefit with respect to lubrication is a built-in asset, you don't have to pay extra for it; the only obligation is to select and use the lubricant as it should be used—intelligently. Quite naturally this requires organization and planning. Organization of the lubrication department,—planning of the lubrication procedure. To this end the lubrication engineer is favored by an assist from the designer who today is adapting revolutionary ideas in machine design, to production. He realizes the need for perfect synchronism of every unit in the assembly line or power plant; accordingly he studies the lubrication requirements of the parts he intends to have built into the machines, as to load-carrying ability, metallurgy, safety and lubrication protection.

Organization and planning also start with thorough knowledge of the lubrication requirements of the machinery. With this as a basis, selection of the most suitable lubricants follows. Here there must be complete understanding between the management, purchasing, maintenance and operating people. The lubrication engineer can well be the coordinator. When he and the maintenance department are agreed that a happy operator is one who has the most dependable production record, the insurance value of effective lubrication becomes more obvious. The operator in reality is the front line man. He has the feel of things. He is normally the first to sense that all may not be well; possibly by sound, even by feeling. Touch can be the first indication of a condition of overheating, just as sound can indicate overload.

Maintenance under such conditions becomes preventive medicine. The organization goes to work to trace the cause before it gets out of hand. In other words modern maintenance goes well beyond the remedy stage. If the condition is due to faulty adjustment of lubrication equipment, correction may not be too difficult. If load, temperature or speed-up are contributing, review of the lubrication requirements is advisable, in line with the physical and chemical characteristics of the lubricants. Change of additives could be helpful in improving load-carrying ability, correcting for foaming or imparting greater detergent action. Increased temperature resistance may be needed, unless the condition of overheating is generated within the mechanism and can be corrected by adjustment.

Then the lubrication engineer is in position to go to management and the purchasing department with whatever recommendation he considers necessary as to change of lubricant. There should be no question of cost. Lubricant performance and insurance value are the primary objectives. The overall cost of lubrication as compared with the protection afforded and the total value of materials handled annually, is relatively insignificant. Down time for maintenance or major overhaul should not be risked at the expense of cost per gallon or per pound of lubricants. The use of purchasing specifications should be approached with due consideration of their limitations. They can be misleading and sometimes are no assurance that the prospective lubricant is best suited for the service. Chemistry and metallurgy can be far more significant. Chemistry, as to the nature and compatibility of additives; metallurgy, as to corrosion resistance of bearing materials, fatigue resistance, compressive strength, hardness, etc. When all these factors are coordinated with the service conditions, the means of lubrication, and the cooperation of operating and management personnel, the value of organization and planning is self-evident.

*Consultant and author "Basic Lubrication Practice."

250,000 Power Tools per year with Cities Service Pacemaker T

Porter-Cable, one of the world's largest manufacturers of portable wood-working tools, has long known the value of quality in a lubricant as well as in a power tool. Each piece of equipment made by Porter-Cable is carefully pretested before manufacture and then continually tested for years after its original appearance on the market. It is this kind of thoroughness that led to Porter-Cable's choice of Cities Service Pacemaker 300 T as the hydraulic oil to power their Fostermatic Screw Machines and Landis Grinders.

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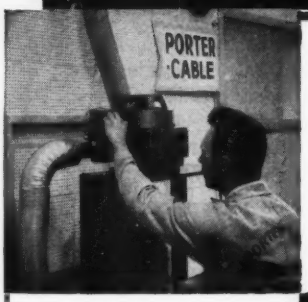


Porter-Cable Research Engineer testing engine for new lawnmower the company will produce soon. All new products undergo extensive research and testing before production.

Backbone of Production Line is Automatic Screw Machine. Pacemaker T gives outstanding performance as hydraulic medium in these machines as well as in Landis grinders and as a general lubricant!

Vol. 15, No. 8

Lubrication Engineering

asle's strength

The backbone of any engineering society is its technical competence and activity. This is the primary reason for its existence. ASLE's organizational structure is based on this premise, which is well reflected in our eleven technical committees and twelve industry councils. The organization unless supplemented by competent manpower is useless, for it is the individual participation that determines the extent of group activity.

One of the real advantages in belonging to a group such as ASLE, is the participation in its technical activities. With the formation of industry lubrication councils a little more than a year ago, the scope of ASLE's activity has been broadened so that virtually every member who is willing to give of his time and energy may participate.

Operating under their respective coordinator here is the list of our technical committees and industry lubrication councils:

Technical Committees	Industry Lubrication Councils
1. Bearings and Bearing Lubrication	12. Aviation
2. Engine Lubrication	13. Machine Tool
3. Fluids for Metalworking	14. Marine
4. Gears and Gear Lubrication	15. Mining
5. Hydraulics and Hydraulic Machinery	16. Mobile Equipment
6. Lubrication Equipment	17. Non-Ferrous Metals
7. Lubrication Fundamentals	18. Paper
8. Lubrication Practices	19. Petroleum and Chemistry
9. Lubrication Rec. and Disposal	20. Power
10. Properties of Lubricants	21. Railroad
11. Seals and Packings	22. Steel
	23. Textile

From this impressive list, there must be a place where you can actively participate in the Technical programs of the Society. The procedure is simple:

Circle the number(s) of the committee or council (or both) on the attached postage-paid, self addressed card and provide in legible form your name and address. The returns will be supplied to the committee and council chairman, who will get in touch with you.

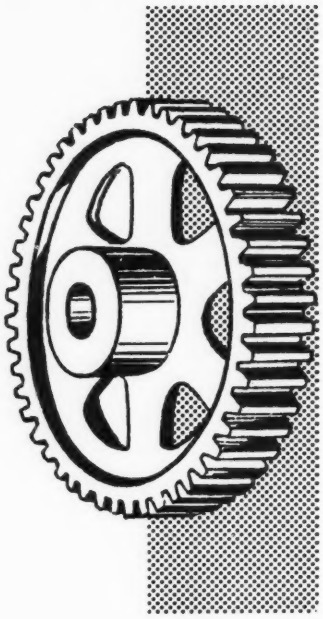
Here is your chance to serve yourself and the Society—don't let it pass!

Calvert L. Willey,
Executive Secretary

Standardized gear rigs are used for specification tests of anti-scuffing properties of oils for jet engines and for marine propulsion gears in the U.S.A. and England. They are also used for testing hypoid gear oils in Germany. Two types of rigs are used, having hunting and non-hunting teeth, respectively; scuffing occurs in a different way in the two cases and correlation between them is not always obtained. However, the scatter of results (or precision of the test) is much the same with the two rigs. Both rigs are claimed to agree well with the full-scale machines.

Repeatability is discussed in the light of test conditions, as well as criteria of failure, the evaluation of tests, and the rating of oils.

The possible effect of different lubricants on the fatigue of metals is recognized, and gear fatigue tests are being added to oil specifications; bearing fatigue tests are already called for in some cases.



The Gear Rig as an Oil Tester

by Earle A. Ryder
West Hartford, Connecticut

A "gear rig" is a machine for testing gears or gear lubricants, generally smaller in scale than the engine or device for which it substitutes, but sometimes consisting of parts of the main device, such as a back-to-back rig made up of two standard reduction gear sets. The feature of the gear rig is that *gears* are used as test specimens. Why use gear rigs for oil testing? While the final answer always comes from a full scale test, it is manifestly impossible to do all our testing in the main gearset, so we require bench rigs of some kind for development work, screening tests, and batch acceptance tests.

Many attempts have been made to correlate simple bench tests with the main gears, with very little success. Experimenters are almost unanimous in concluding that a *performance* test using gears is therefore required. Watson (Int'l Gear Conf. 1957) reviewed this question again and stated: "A particular feature of lubricant testing machines is their apparent inability to agree in the ranking of a series of oils." Again, Mansion (1) after much experience concluded "It would seem that the best method of testing gear lubricants is by lubricating gears with them."

Further justification is hardly needed since a number of current oil specifications require gear lubricating properties to be demonstrated in a standardized gear rig.

Presented before the ASLE Gear Symposium, January 1959 at Chicago, Illinois.

GEAR RIG TESTS IN OIL SPECIFICATIONS

Gear failures influenced by the lubricant are *scuffing*, which is a quickly occurring surface failure consisting of local welding and tearing apart, and *pitting*, which is a surface fatigue failure and generally takes some time to develop. Gear rig tests for anti-scuff values are required by present specifications in the U.S.A. (using Pratt & Whitney or Ryder test) for lubricants such as MIL-L-7808 Aircraft Turbine Engine Oil, Synthetic, and MIL-L-17331 (Ships) Steam Turbine Lubricating Oil. Similarly, British Specifications call for the use of the IAE gear machine in DERD-2487 Aircraft Turbine Engine Lubricating Oil, Synthetic, and Admiralty E. in C. No. 0-6 Steam Turbine Lubricating Oil OEP-90.

In addition to scuffing tests, tests of the effect of the lubricant on the *fatigue* of gears will soon be incorporated in some oil specifications. Later in this paper it is shown that the life of gears may vary by 10:1 when using different oils. The fatigue effect in ball bearings would be expected to be like that in gears, and in fact this is recognized in specification MIL-H-19457 (Ships) Hydraulic Fluid, wherein as part of the qualification tests the lives of certain angular contact ball bearings must be measured while running on the test fluid, and compared with lives of similar bearings run on a reference fluid.

Whereas in the U.S.A. and England gear rig tests are now required only for some jet engine oils and

some ship gear oils, in Germany hypoid gear oils are subjected to similar tests in the FZG rig, which is somewhat like the IAE.

GEAR RIG TYPES

Various designs of gear rigs have been used, most of them employing spur gears. They are used for testing lubricants for spur or bevel gears, although the FZG rig, as already noted, is being successfully used for hypoid gear oils. A helical gear machine with shafts set at 15 degrees from each other was used by Wickenden (2) to stimulate hypoid gear action, but it has not come into general use.

TABLE 1. CHARACTERISTICS OF SOME GEAR RIGS

Name	I.A.E.	THORNTON	FZG	SHELL DEV	RYDER‡	WESTERN GEAR
Reference		(3)	(4)	(10)	(5)	
Center Dist., in	3.25	5.0	3.6	3.0	3.5	2.0
Gear Face, in	0.188	0.428	0.79	0.25	0.25	0.375
no. Teeth	15–16	24–26	16–24	17–19	28–28	32–32
Dia. Pitch	4.769	5	5.65	6	8–10	16
H.P. of Drive	4.5	30		40	40	40
Max. Speed, rpm	6000	12000	12000	30000	15000	30000
Max. Load, lb per in width	12800	5000	4200	7080	5000	6000
Load applied while running	no	no	no	yes	yes	yes

‡Note: In accord with current usage, the Pratt & Whitney Aircraft Gear and Lube Tester will be referred to as the Ryder rig.

The main features of six familiar machines are shown in Table 1. All are of the power-circulating type: there are two basic differences among them, namely, the method of applying load to the gear teeth, and the use of hunting or non-hunting teeth. In the IAE, FZG and Thornton machines, the load is applied while the gears are not turning and cannot be adjusted after starting a run. In the Shell, Ryder, and Western machines, load can be changed while running; this is at least a convenience, and there is something to be said for not starting under full load.

CORRELATION WTH MAIN GEARS

By correlation in this context it is meant that the gear rig should rank oils in the same order of merit as the main gearset, not that the exact load the main gears can carry should be predicted.

On the question of correlation the situation seems to be good, in that the IAE machine interprets British aircraft engine requirements and the Ryder machine satisfies the American engines. Correlation of the two machines, using the same test oils, has not been very good; this may be largely due to the unavoidably large scatter in ratings from both machines. At any rate, both machines are in use in their respective fields, and nothing has been offered to replace them. Information is lacking about the other machines listed.

TABLE 2. SAMPLE SCUFFING TEST CONDITIONS

Test	RYDER (6)	IAE (7)
Speed, rpm	10000	2000, 6000
First load, lb per in width	371	610
Load added, each step*	371	305
Length of each run, min	10	5
Rest between runs, min	n.s.**	5
Oil flow to test gear, cc per min	270	284, 568
Oil in temperature, deg F	165	230
Failure criterion, per cent of tooth scuffed	22½	100

*FZG adds increasing load increments
**not specified

RANGE OF CONDITIONS POSSIBLE

The ranges of conditions possible in the listed rigs are not widely different. Choice of conditions and procedure are fully as important as apparatus, and Table 2 compares some standard test conditions for the IAE and Ryder machines. Much more drastic conditions may be chosen, since some machines in current use can be run at temperatures to 700F, and at high speeds. Test requirements can be made much more severe than they now are, without redesigning the basic test equipment.

In the Ryder machine induction heating of the test gears may be used as shown in Fig. 1, along with high oil squirt temperatures. So long as the temperature of the oil supplied to the plain bearings of the machine is kept down, the gears and the test oil may be run very hot. A roller bearing modification of the rig for high speed use has been built by Southwest Research Institute and is undergoing shakedown tests.

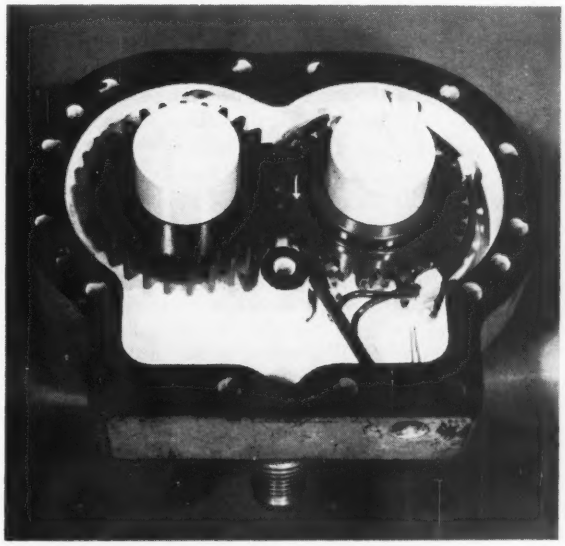


Fig. 1. Ryder Gear Head with induction heating coil.

REPEATABILITY

Although the gear rig provides a usable test, the precision of the oil ratings obtained is not as good as might be desired; considerable unavoidable scatter is present. (This is true for the main gears too, but since so few tests on them are reported, it is not generally realized.)

The scatter of results of either scuffing or fatigue tests cannot be eliminated and is something one must live with. Gillett, (8) one of the greatest authorities on engineering materials, said "Scatter is the primary, underlying problem in the use of engineering materials." Referring to wear testing, (and the present paper discusses a form of wear, as influenced by the lubricant), Gillett stated, "Adjusting the test method so it will give reasonably reproducible results on the same material is difficult; selecting test conditions so that tests place materials of known performance in service, in the right order is more difficult; and interpreing test results on a new material into terms of future service behavior, most difficult of all."

Although the gear rigs are not used to predict full scale performance but rather to compare one oil with another, one can only be confident of detecting large differences between oils and must not try to read any hair-splitting conclusions into the results.

The prevailing test rigs are for measuring *relative*, not *absolute* values. Errors are present, due to bearing friction, hydraulic effects, etc., but for routine testing it is not necessary to correct for all of them.

Since the aim is only to compare oils, and usually to compare untried oils with the oil employed in experimental development of the main gearbox, it would seem that a reference oil scheme might be feasible. This would in principle be similar to the procedure for knock rating of gasoline, which is also done in a small-scale, bench, performance test. The variation or scatter in oil rating tests is partly due to changes or differences in the apparatus used. Supposedly any such change might affect different oils in the same way, and if so the reference method would minimize its effect on ratings. Unfortunately this promise is not alwavs realized, as test data frequently show less spread in absolute values than in relative ratings.

Dealing with the scatter problem simply involves recognition of the fact that the confidence of a single test is low, and confidence increases as replicate tests are added. Using a reference scheme does not change this basic principle.

Two ways of dealing with the scatter problem are illustrated by different issues of specification MIL-L-7808. 7808C calls for eight determinations of load-carrying capacity in the *qualification* test, and requires 1870 ppi (pounds per inch width of gear) minimum. For the *batch* acceptance test, however, the minimum load requirement is scaled according to the number of tests made, as follows: (read first and second columns)

No. of determinations	Av. results, ppi	Per cent of reference B
2	2100	78
4	1990	74
6	1930	72
8	1870	70

Thus a statistical basis is used for recognition of the scatter effect.

The current procedure, 7808D, includes the use of a standard reference oil, and a relative rating of each test oil is obtained as a percentage of the reference oil rating *on the same machine*. The third column, above, shows minimum requirements. Certain rules are established for determining the reference oil rating to be used. As noted above, this system may not result in more accurate ratings.

STANDARDIZED CONDITIONS ARE IMPERATIVE

Physical science is based on the belief that nature is orderly; that is, that the same cause will always produce the same effect. In a random process such as wear, variations will always be present, but excessive variation in test results indicates a failure to keep all conditions constant.

Great effort has been made to improve the repeatability and reproducibility of tests. Changing the test conditions or apparatus have little effect. The *constants* such as speed, oil flow, oil temperature, load, test gears, etc., must really be held constant; moreover, the assembly and maintenance of the apparatus must be done in a controlled manner. For instance, a change in the exact torque used to screw on the housing cover nuts can alter the indicated scuff load by varying the alignment and, hence, the friction of the bearings.

TEST GEARS—SUPER GEARS

In using gears as test specimens it seems important to have all the gears alike as to geometry, chemistry, and metallurgy as one would expect that the variations in results would be less if the variation in gear characteristics were smaller. To determine the importance of geometry, Southwest Research ran a series of tests on two lots of gears, one from regular production, and the other specially selected to *master gear* limits, for tooth form, spacing, concentricity, etc. The super gears had a higher scuff limit, but more scatter than the standard gears. However, this does not prove that the gears should be made worse rather than better.

While the Ryder gears have unmodified involute form, the IAE gears have tip relief, which is also a feature of full-scale practice. Since it is desired to have precisely the same tooth form on all gears of a kind, rather than to demonstrate the maximum load capacity, the true involute form has some advantages. Tip relief does not improve repeatibility.

Among the machines listed in Table 1 there are only two principal differences, namely, the method of applying load to the gear teeth, and the use of hunting or non-hunting teeth. These differences may account for difficulty in matching results from different machines, but should not have any influence on repeatability.

An advantage of non-hunting teeth is that one or more bad teeth do not print all the way round on the mating gear, since each tooth meshes with only one tooth of the other gear. With the best of hard gears perhaps 10 per cent or so out of a lot of tests will show slight eccentricity or a couple of proud teeth.

The FZG gears are what might be called part-hunting. Any two opposite teeth of the 16-tooth gear engage three particular teeth of the 24-tooth gear and no others. As might be expected, scuffing is progressive, much as in the Ryder test.

CRITERION OF FAILURE—END POINT OF TEST

It is noteworthy that for scuffing tests different people have all arrived at the same general procedure, which is to run the gears under a constant load for a short time (5 to 10 min.), stop the machine to examine the gear teeth, then run for another period at a higher load and so on until a certain amount of scuffing is observed.

Among the many things that affect the reliability of a test, none is more important than establishing a definite end-point, or failure load. The manner in which the end point is determined in the tests under discussion will be considered. In the case of unequal gears (hunting teeth) the manner of failure of the gear tooth surface seems to be quite different from that which occurs with non-hunting teeth. In scuffing tests on the IAE machine, for instance (hunting), little or no distress is shown as the load is progressively increased, until a critical point is reached when smoke appears in the gearbox, torque increases, and when examined at rest the gears are generally scuffed on approach and recess portions of all teeth. On the other hand with equal gears (as in Ryder test) some scuffing may occur at the tip and root of the teeth at a fairly low load. With most oils this scuffing will not increase in extent even if the run is continued for a long time. When the load is increased, however, the scuff area becomes larger, as is likewise the case in full-scale gears. It is therefore necessary to fix upon a certain degree of scuffing or a certain area of scuffed teeth as the criterion of failure or the end-point of the test. An arbitrary figure of 22½ per cent of the working area of tooth face was proposed many years ago, and is in general use. This is equivalent to ⅔ of the teeth scuffed on ⅓ of their area.

It would seem offhand that the catastrophic scuffing of the IAE gears would signal a definite and reliable end to the test, but after long experience, practitioners are still far from agreement on the interpretation of IAE tests. Standard deviations reported for IAE tests are as large or larger than those usual for Ryder tests. It is safe to say that there is no substantial difference in the usefulness of these two tests in their respective fields.

As noted above, very accurate or super gears have been found to raise ratings, but if anything, to increase scatter. Tip relief, used in IAE gears but not in Ryder gears, does not improve the precision of tests, although it lowers the slope of the scuff vs load curve; that is, scuffing increases more slowly as load is added, than with true involute gears.

INTERPRETATION OF TESTS—RATING OF OILS

There remains one factor that has not been reduced to mechanical terms, and this is the decision as to when the agreed-on degree of scuffing is reached. This is an operator decision.

In the case of the hunting tooth machine the operator has only one decision to make, and that is whether the gears are scuffed or not scuffed. He may remember the scuffing load for the previous run, and there will be a strong tendency to try to make the answer come out the same on successive runs. This may be unconscious but it is there just the same. With the other type of machine the operator has to examine 28 teeth and write down a number for each one. He cannot know how his average is going to come out, and he cannot remember how all the teeth looked the time before, so an impartial assessment is probable.

The Ryder test as described by WADC (6) is evaluated by visually estimating after each run or step, the per cent of the working area of each tooth that is scuffed (grinding marks obliterated). It is found that different operators agree closely on the assessment of a given gear. This is also true if they are inspecting photographs of the teeth instead of the actual gear.

The test is continued in ten minute steps until the average scuff on all teeth is more than 40 per cent. A curve is then plotted on semilog paper, showing log of per cent scuffed vs load oil pressure. The intersection of this curve with the 22½ per cent line determines the load rating of the oil for the particular run. There is no uniformity of the rate of progression of scuffing in different tests. The rate of progression of scuffing is a random effect, and it does not correlate with gear hardness, surface finish, or other variables. As a result, operators' scuff curves have all possible shapes from straight lines to ogives.

It might be suggested that a mechanical scheme for the analysis of scuff data would eliminate some variations that might reflect operator judgments in drawing the curves. This has been tried, making the assumption that a straight line on the semilog plot represents the data well in most cases, and locating this line by a least squares method. The author has recalculated many ratings by this means, generally without getting much change from the original operators' ratings.

An interesting feature is that the mathematically determined slopes of the scuff curves vary by a large factor, ranging between 3:1 and 10:1 for a series of similar tests. In other words, the increase of scuffing following a given increase of load is different for every test. This shows (if further evidence is needed) that a random effect is being dealt with that can never be tamed. One can never expect to get a precise answer from a single test.

Does this conclusion make it useless to try to improve testing? Not at all. The case is simply that there are causes of error that can be abated, and other causes that nothing can be done about. It is important to eliminate the errors that can be avoided.

OIL AND THE FATIGUE OF METALS

Gear rigs have been useful in studying the fatigue

of metals, a subject which almost requires the use of bench, rather than full-scale, tests. The subject of *wet fatigue*, or the influence of the lubricant on surface endurance of gears, has barely been scratched. The literature frequently mentions wet fatigue, but usually as a side issue, and few suggestions have been made for dealing with it. Otterbein (9) for example, showed 8:1 difference in the lives of roller bearings lubricated with different oils. Gear rig tests made by Pratt and Whitney Aircraft showed about 10:1 difference in the lives of gears. Current engines are designed to use current oils, but if oils could be picked out which would insure a 5:1 or 10:1 improvement in gear and bearing life, these parts could be made lighter and smaller.

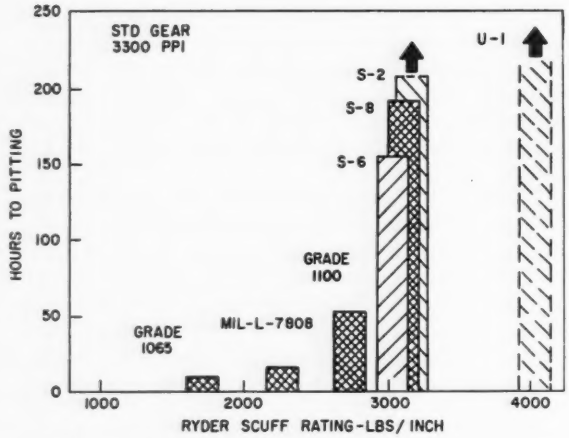


Fig. 2. Avg. gear fatigue life vs Ryder scuff rating.

Fig. 2 shows relative lives of similar gears, run in the presence of different lubricants. Each bar shows the average of four to six tests, and it is seen that a difference of 10:1 exists between the lowest and highest lives. It is amazing that so little attention has been paid to this phenomenon, when the effect can be so great. It is nothing new, for the literature abounds in reports of tests of all kinds (tension, torsion, tri-axial stress, rolling contact) in which wetting the specimens with different liquids was accompanied by large differences in fatigue lives.

There is no doubt whatever that oils play some part in the fatigue of lubricated surfaces, but the mechanism is not yet understood. In the meanwhile an empirical approach will dictate gear and bearing fatigue tests, to select suitable, and reject unsuitable oils.

Fig. 2 shows an apparent correlation between anti-scuff value and fatigue life. It should not be assumed that this is a general rule until many more data are recorded. The important fact is the enormous variation in lives. One should also keep in mind that these data are valid for a certain set of conditions and perhaps can not be extrapolated to the main engine.

SUMMARY

The questions that have been reviewed and their answers are as follows:

Question: Why use gear rigs at all?
Answer: Because no workable substitute has been offered.
Question: Are present rigs obsolete, in view of new conditions?
Answer: No, test conditions can be made much more drastic than they are at present, without much change in existing rigs.
Question: Do rig tests correlate with full-scale experience?
Answer: Yes, well enough for a working basis; the IAE machine interprets British aircraft engine requirements, and the Ryder machine satisfies American engines.
Question: What about repeatability?
Answer: It is not too good, but can be improved somewhat. However, we shall always have to use a statistical approach.
Question: Are present oil ratings meaningful?
Answer: There is no doubt that the answer is yes. Many people are trying to improve the rating process, and little by little some of the present difficulties will be overcome.

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COMMENTS by V. N. Borsoff

Shell Development Company, Emeryville, California

Throughout Mr. Ryder's paper "The Gear Rig as an Oil Tester" the scatter or poor reproducibility of results obtained with his gear rig was mentioned. Mr. Ryder explained this scatter by "randomness" of the scoring phenomenon and concluded that the scatter cannot be eliminated, and that we have to live with it. We still do not agree with this. In the writer's recent paper,[1] scoring is a reproducible phenomenon

[1] *Borsoff, V. N., "On the Mechanism of Gear Lubrication," ASME paper 58–LUB–4 presented at ASLE-ASME Lubrication Conference, Los Angeles, Calif., Oct. 13–15, 1958.*

and can be evaluated with a considerable degree of accuracy. The reproducibility, in our case, was attained by employing accurately constructed test gears, accurately aligning them throughout the test, using the addendum of the driver gear as a reference surface, and distinguishing between scoring, abrasion, burnishing and other surface disturbances. Thus we also question Mr. Ryder's statement that the scatter was higher with more accurate gears.

It appeared also that the gradual development of scoring noted by Mr. Ryder with the non-hunting teeth combinations is not a peculiar property of the non-hunting teeth systems, but rather could be explained by inaccuracies of the gears used. If all the teeth were exactly alike they should be affected in the same manner.

COMMENTS by P. M. Ku

Southwest Research Institute, San Antonio, Texas

As father of the gear test machine which bears his name, Mr. Ryder is responsible, basically more than anyone else, for the use of the gear rig as an oil tester in this country. Gear rig tests of one sort or another are now used, both in this country and abroad, to determine the scuff-limited load of lubricants for aviation, marine and other applications. Gear rigs are also being used to study the effect of lubricants on gear tooth surface fatigue or pitting. Because of the widespread use of gear rigs in lubricant testing, it is important that as much be known about the physical and statistical significance of the gear rig tests as possible. For this reason, Mr. Ryder's authoritative appraisal of the state of the art is most timely and welcome.

The writer's organization has been engaged in the development and refinement of gear lubricant tests for several years. Some of the results of our work on gear tooth surface fatigue have been reported in a recent paper. (1) The present discussion will be concerned only with tests which may broadly be described as scuffing or wear tests. In presenting our views on this subject, my purpose is—as the Chinese say—merely "to add small ornamentation to a work of art." I only hope that these ornaments will not be found entirely superfluous.

First of all, I do not believe that any one will argue seriously with Mr. Ryder about the use of gears as test specimens in interpreting gear lubricant performance. Call it a model test or the empirical approach if you wish, we know of no better way to handle the problem today. But in order to apply the model test properly, we must observe certain rules of the game. We must carefully select the design and operating conditions for the model to suit the problem at hand. Unless we have proof to the contrary, we cannot assume that the results obtained for one set of conditions will automatically apply to another set of conditions. This point has been well emphasized by Mr. Ryder.

Now, the converse of the above argument also seems to merit some attention. It is that, unless proven otherwise, we must be cautious in applying the results obtained under different sets of conditions to basically the same problem. This brings to mind two related questions about the Ryder gear machine and the IAE gear machine: 1. Which machine (granting proper operating conditions) gives better correlation with actual service, and 2. Do they give results that correlate with each other? Mr. Ryder has commented on the design differences of the two machines, as well as the different criteria for defining lubricant "failure." In view of these differences, one may wonder as to which machine or test method speaks better for any given application. In raising these questions, I am not suggesting that if one machine is satisfactory, then the other must necessarily not be. Perhaps both are satisfactory with, say, suitable choice of operating conditions; but this point needs yet to be firmly established. Further, if both are satisfactory, then their results should correlate with each other, but data of this type are, as Mr. Ryder states, not yet in evidence. It seems that these questions should be answered, one way or another.

We now turn to the question of test precision. Here, we are in general agreement with Mr. Ryder, and some of the data that we have collected may be of interest.

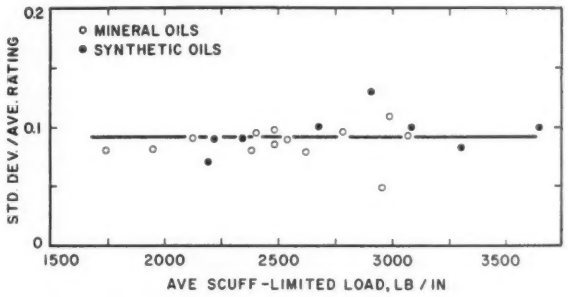

Fig. A. Repeatability of the standard Ryder gear test for determining scuff-limited load. Repeatability refers to variability of results associated with single test rig.

Figure A presents data on the repeatability of the standard Ryder gear test. The term "repeatability" is used here to indicate the variability of test results associated with any single test rig. The data are drawn from tests conducted by the writer's organization as well as results reported by a number of laboratories participating in a series of cooperative test programs initiated by Wright Air Development Center (WADC). In this figure, the ratio of standard deviation to average rating is plotted against the average rating. Note that this ratio remained nearly constant at 0.09 over a wide range of rating level.

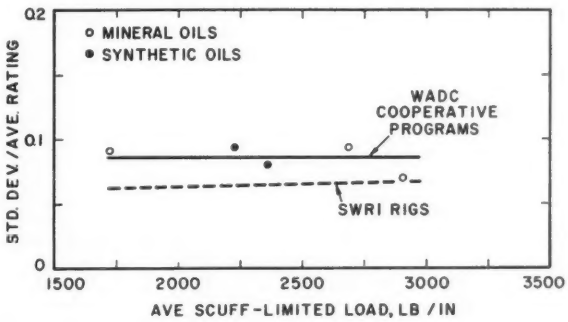

Fig. B. Reproducibility of the standard Ryder gear test for determining scuff-limited load. Reproducibility refers to variability associated with the average results obtained from the different test rigs.

In Fig. B, data on the reproducibility of the standard Ryder gear test are presented in a similar manner. Here, reproducibility refers to the variability associated with the average results obtained from different test rigs. Note that the ratio of standard deviation to average rating remained nearly constant at 0.085 over a wide range of rating level,

on the basis of the WADC cooperative test programs. The fact that a somewhat better reproducibility was realized at SwRI seems to reflect the benefit of more rigid control over equipment and test procedure details that are more readily obtainable in a single laboratory. For the sake of clarity, the actual points for the data from the writer's organization's tests are not shown in this figure.

Table A shows the effect of test gear tolerances on the Ryder gear rating. All tests were conducted on the same machine at SwRI, using test gears of standard Ryder gear geometry, but of different tolerances. The "early model test gears" are standard Ryder gears available up to the early part of 1956. The "late model test gears," those produced after the above date, are identical to the early model test gears except for improved concentricity. The "special precision gears" refer to gears selected from the standard production lot to give tolerances of the "master gear" class. It will be

TABLE A. EFFECT OF TEST GEAR TOLERANCES ON THE RYDER GEAR TEST

		EARLY MODEL TEST GEARS	LATE MODEL TEST GEARS	SPECIAL PRECISION GEARS
Gade 1065	Ave. Rating	1950	2400	—
(MIL-L-6082)	Std. Dev.	157	189	—
	Std. Dev./Ave.	0.08	0.08	—
Oil "A"	Ave. Rating	2360	2930	—
(MIL-L-7808)	Std. Dev.	218	365	—
	Std. Dev./Ave.	0.09	0.125	—
Oil "B"	Ave. Rating	2200	—	2690
(MIL-L-7808)	Std. Dev.	154	—	280
	Std. Dev./Ave.	0.07	—	0.105

noted from Table A that improved gear tolerances increased the rating level, but at the same time increased the scatter of the test results. Note that for all data presented in Table A, the ratio of repeatability standard deviation to average rating was nearly constant at 0.09. This seems to suggest that, within the range of tolerances encountered, improved gear tolerances had little effect on the degree of test repeatability.

We have also examined the precision of a few other test methods. It was argued that the poor repeatability of the standard Ryder gear test might have been due partly to the normal variability of the test gears. It appeared that a comparative rating procedure, whereby the performance of the test lubricant could be compared with that of a reference oil, by using the same mating side of the test gears in the same test rig, would alleviate this objection.

Fig. C shows the principle of a "comparative scuff test" that we studied. First, we ran the test using a reference oil, following the standard Ryder gear test procedure, up to 24 psig load oil pressure (or up to some arbitrary gear tooth load). After ten minutes at this load, the average per cent scuff on the gear teeth was visually determined. The oil system was then drained and flushed, and the test oil introduced. The test was then repeated with the test oil, using the same mating side of the test gears, to a load oil pressure giving at least 50 per cent average scuff. The load oil pressure at which the increase in scuff obtained with the test oil was equal to the scuff obtained on the reference oil at 24 psig load oil pressure, was determined from the scuff versus load oil pressure plot. The scuff-limited load was then computed.

We also experimented with a comparative wear test, which employed essentially the same technique except that the rating was based upon wear or metal removal (measured by radioactive means), instead of scuffing.

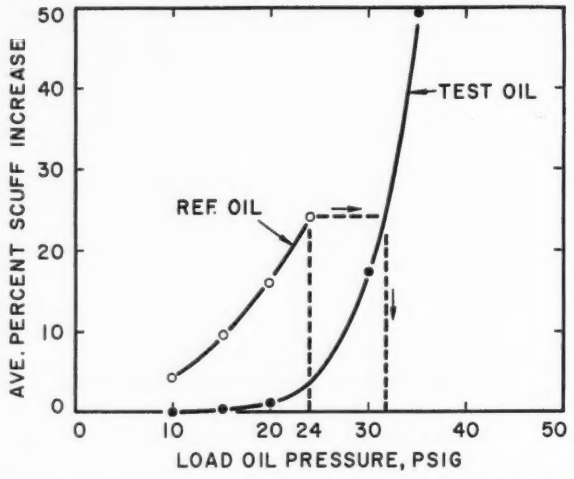

Fig. C. Plot showing the principle of the "comparative scuff test."

TABLE B. PRECISION OF SEVERAL TEST METHODS

TEST METHOD	STD. DEV./AVE. RATING: REPEATABILITY	STD. DEV./AVE. RATING: REPRODUCIBILITY
Ryder Gear Test	0.09	0.085
Comparative Scuff Test	0.07	0.11
Comparative Wear Test	0.07	—
Borsoff Test	0.085	—

A comparison of the repeatability and reproducibility of the above test methods is presented in Table B. This table also shows the repeatability of the gear test described by Borsoff (2), based on limited data contained in a recent paper. It is well to emphasize that Table B includes data on a rig using hunting teeth (Borsoff), and one using non-hunting teeth (Ryder). In the case of the latter rig, test methods of entirely different principles were used. Yet all these methods gave approximately the same fractional repeatability. This would seem to indicate that the inherent precision of this class of tests as they now stand is not much affected by the test equipment, test gears or test procedure. It is likely that the scatter obtained with such tests is largely the result of the randomness of the wear or scuffing process.

Table B also shows that the reproducibility of the standard Ryder gear test and the comparative scuff test, both based on the average results reported by laboratories participating in the WADC cooperative test programs, were roughly equal. It is believed that significant improvement in reproducibility is possible through strict standardization of the test equipment and test procedure. This possibility is suggested by the SwRI data presented earlier in Fig. B.

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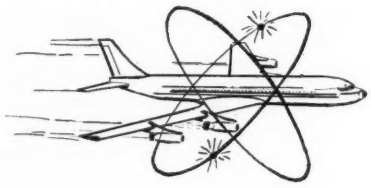
Comparison of Dynamic and Static Irradiation Tests of Aircraft Fluids



by R. J. Neely

Convair Division of General Dynamics Corporation, Forth Worth, Texas

Four examples of dynamic and static irradiation of aircraft fluids are presented. The dynamic samples were irradiated while operating in component aircraft systems. The static samples were placed to receive approximately the same integrated flux dose. Static and dynamic results were divergent.

Such standard evaluation tests as viscosity, specific gravity, and index of refraction indicated that breakdown of the fluid was accelerated by operating in a nuclear environment. Predictions of the service life of these particular fluids could not be based on static irradiation. Changes generally occurred most often in the viscosity and neutralization number of the fluids.

Most of the data published to date on the properties of irradiated fuels, fluids and lubricants have been obtained with gamma sources under static conditions. Although these laboratory measurements are an excellent method of preliminary screening, they are poor indicators of a product's behavior in a system operating in the mixed radiation field of an aircraft power reactor. As shown by the results reported in this paper, dynamic tests in a reactor radiation environment are essential because the static gamma tests do not reflect what occurs in flight.

The data reported here were obtained in conjunction with a System Panels Test. In this test (1), advanced aircraft systems were operated for 500 hours in the proximity of the Ground Test Reactor (GTR). Dynamic conditions were similar to those which the systems would encounter in flight. Inasmuch as these systems contained fuel, fluid, or lubricant, it was a simple matter to remove test samples of these substances at intervals during the irradiation. To check the dynamic results, static samples were placed so that they would receive approximately the same integrated flux as the bulk of the fuel, fluid or lubricant in operating aircraft equipment. Only in a very few instances did the results from static and dynamic tests coincide. The characteristics of some of the static samples changed in one direction while those of the dynamic samples changed in another. Four cases, which seem typical of the spread in results, have been selected for discussion.

TEST ON MIL-L-7808C

The first case deals with an oil meeting specification MIL-1-7808C (Lubricating Oil, Gas Turbine, Aircraft) which was operated in a jet engine gear box (1). The results are shown in Table 1. The gear box was to be operated in a nuclear field for 500 hours or until system failure. The failure occurred at 232 hours. A similar gear box used as a control operated for the full 500-hour operation cycle without malfunction or lubricant failure.

A lubricant failure is indicated at 1.5×10^{14} neutrons/cm^2 (232 hours of operation). At first, it was thought that dilution had occurred from a nearby JP-4 fuel reservoir, but subsequent testing eliminated this possibility. At the same time as, or shortly after the lubricant failure, the gear box failed through gear fatigue. As can be seen in Table 1, the decrease in viscosity and the rise in neutralization number were excessive. The static sample of MIL-L-7808C oil, which was subjected to 500 hours of irradiation or nearly double the time of the dynamic test oil (the final 250 hours being at a much higher reactor power level), did not exhibit the same degradation. Although the neutralization number climbed in the same degree as the dynamic sample, the viscosity did not decrease but rose slightly. The other properties remained essen-

TABLE 1—EFFECT OF RADIATION ON MIL-L-7808C
(Lubricating Oil for Aircraft Gas Turbine)

SAMPLE NUMBER	TOTAL NEUTRON FLUX (10^{14} N/cm²)	TOTAL GAMMA DOSE (10^6 Roentgen)	VISCOSITY @ 100°F, Cs	VISCOSITY @ 210°F, Cs	NEUTRALIZATION NUMBER	BROMINE NUMBER	SPECIFIC GRAVITY @60/60°F
Control	0	0	13.84	3.70	0.33	0.0	0.9225
1	0.61	2.1	13.45	3.42	2.30	1.71	0.9210
2	1.14	3.9	13.39	3.40	2.30	1.65	0.9205
3	1.49	5.2	13.43	3.37	3.06	1.88	0.9205
4	1.97	6.7	3.57	1.38	4.28	1.24	0.9220
Static	10.25	35	15.03	3.58	5.99	2.20	0.9225
Military Specs.			11.0 min.	3.0 min.			

tially the same. It should be pointed out again that the integrated flux necessary to produce a given neutralization number change was much greater for the static than for the dynamic sample.

It would have been impossible to predict on the basis of static irradiation data, how a MIL-L-7808C oil would function in a gear case. The characteristics of the static sample remained fairly constant and did not exhibit the radical changes which occurred under operating conditions.

TESTS ON MIL-L-6081B AND MIL-F-5624C

The next case, which does not show as great a difference between static and dynamic specimens, deals with a jet engine nose case which used both MIL-L-6081B (Oil, Lubricating, Jet Engine) Grade JP-4 (1). Unfortunately, there was a mechanical malfunction of the fuel pump after 232 hours of irradiation. This failure precluded further dynamic testing on the JP-4 fuel. Data on the MIL-L-6081B Grade 1005 Oil and JP-4 Fuel, are presented in Tables 2 and 3 respectively.

The MIL-L-6081B, Grade 1005 oil, operated satisfactorily for 500 hours in a nuclear environment. Both the dynamic and static samples received an integrated neutron flux of 10.3×10^{14} neutrons/cm² and a gamma dose of 3.5×10^6 Roentgen. Only two differences can be noted in the data on the final dynamic sample and the static sample: the bromine number of the static sample increased slightly and the neutralization number of the dynamic sample increased considerably. It is felt that in view of the difficulties encountered previously with the MIL-L-7808C oil, the

TABLE 2—EFFECT OF RADIATION ON MIL-L-6081B
(Jet Engine Lubricating Oil—Grade 1005)

SAMPLE NUMBER	TOTAL NEUTRON FLUX (10^{14} N/cm²)	TOTAL GAMMA DOSE (10^6 ROENTGEN)	VISCOSITY @ 100°F, Cs	VISCOSITY @ 210°F, Cs	REFRACTIVE INDEX N_D(20°C)	BROMINE NUMBER	NEUTRALIZATION NUMBER
Control	0	0	5.11	1.64	1.4645	1.32	0.47
1	0.61	2.1	4.97	1.74	1.4650	1.25	0.21
2	1.14	3.9	5.00	1.63	1.4646	1.15	0.04
3	1.49	5.2	5.00	1.62	1.4647	1.09	0.04
4	1.97	6.7	5.01	1.61	1.4656	1.25	0.04
5	3.72	12.7	5.02	1.64	1.4649	1.45	0.10
6	5.16	17.6	5.03	1.64	1.4652	1.37	0.10
7	6.6	22.8	5.04	1.68	1.4658	1.08	0.30
8	8.28	28.3	5.29	1.68	1.4652	1.19	0.51
9	10.3	35	5.45	1.71	1.4662	1.48	1.01
Static	10.3	35	5.48	1.70	1.4650	2.79	0.15
Military Specs.			5 min.				

TABLE 3—EFFECT OF RADIATION ON MIL-F-5624C
(Aircraft Engine Fuel—Grade JP-4)

SAMPLE NUMBER	TOTAL NEUTRON FLUX (10^{14} N/cm²)	TOTAL GAMMA DOSE (10^6 ROENTGEN)	SPECIFIC GRAVITY @60/60°F	BROMINE NUMBER	NEUTRALIZATION NUMBER	BITUMENS SLUDGE & WATER (%)	REFRACTIVE INDEX N_D(20°C)
Control	0	0	0.7678	0.64	0.60	Trace	1.4222
1	0.61	2.1	0.7640	0.62	0.13	0.1	1.4219
2	1.14	3.9	0.7720	0.36	0.04	0.1	1.4242
3	1.49	5.2	0.7657	0.68	0.04	0.1	1.4421
Static	10.25	35	0.7480	1.52	0.07	Trace	1.4218
Military Specs.			0.739 to 0.780				

TABLE 4—EFFECT OF RADIATION ON MIL-F-5624C
(Fuel for Aircraft Jet Engines—Grade JP-4)

SAMPLE NUMBER	TOTAL NEUTRON FLUX (10^{11} N/CM^2)	TOTAL GAMMA DOSE (10^6 ROENTGEN)	SPECIFIC GRAVITY @60/60°F	BROMINE NUMBER	REFRACTIVE INDEX N_D(20°C)	NEUTRALIZATION NUMBER	BITUMENS SLUDGE & WATER (%)
Control	0	0	0.7686	0.73	1.4305	0.20	0.0
1	5.9	2.37	0.7732	0.98	1.4309	0.03	1.50
2	1.11	4.44	0.7775	1.04	1.4340	0.06	0.86
3	1.48	5.92	0.7715	0.75	1.4340	0.15	3.10
4	1.93	7.70	0.7698	1.47	1.4279	0.34	—
5	3.63	14.5	0.7762	0.97	1.4390	0.21	4.20
6	5.04	20.1	0.7766	—	1.4328	0.38	1.12
7	6.52	26.0	0.7728	0.75	1.4388	0.39	2.10
8	8.07	33.3	0.7765	0.92	1.4260	0.41	0.63
9	10.0	40	0.7741	0.89	1.4378	0.50	Trace
Static	10.0	40	0.7480	1.52	1.4218	0.07	Trace
Military Specs.			0.739 to 0.780				

neutralization number was of greater significance than the bromine number. While it can only be conjectured, it is believed that a failure of the MIL-L-6081B oil was imminent. However, this oil did operate satisfactorily for a 500-hour period in the absence of irradiation. Thus, it may be concluded that irradiation of this system caused oxidation of the MIL-L-6081B oil which static irradiation did not indicate.

In Table 3, very minor changes are observed between the 200-hour dynamic sample (Sample No. 3) and the 500-hour static sample. As with MIL-L-7808C, the integrated flux received by the JP-4 fuel static sample was much greater than that received by the dynamic sample. No trends were evident from the dynamic samples and no prognostication could be based on the static sample since its physical values changed very little from those of the control sample.

TESTS ON MIL-F-5624C

Case three deals with another fuel system using MIL-F-5624C (Fuel Aircraft and Jet Turbine) Grade JP-4 (3). The results differ from those discussed previously on JP-4 fuel. These data are presented in Table 4. Due to sampling procedures, the bitumens, sludge, and water value for the final dynamic sample is not indicative of the amounts of "mayonnaise" type sludge found in the fuel reservoir and throughout the system after teardown. Conversely, neither sludge nor sediment was found in the static sample container. The other changes in the dynamic samples differed sufficiently from the static sample to indicate that a "go" or "no go" prediction could not be based on the statically irradiated fuel sample.

TESTS ON MIL-L-6085A

Case four, which shows the difference between irradiated and non-irradiated dynamic systems contained MIL-L-6085A (Lubricating Oil, Aircraft Instrument—Low Volatility) in the pneumatic panel (2) under both irradiated and non-irradiated dynamic conditions. Table 5 contains the data obtained from samples of this oil. One batch of oil was run under a non-irradiated condition and then drained. The system was then refilled and operated in a nuclear environment for the same length of time. While most of the changes were minor, the neutralization number increased considerably. A static control sample was not available for this system, so comparisons cannot be made between statically and synamically irradiated samples. Some MIL-L-6085A oil which is being irradiated statically at present, has not exhibited degradation.

CONCLUSIONS

It is believed that the four cases discussed here are typical of the fluid data obtained for operating systems. Although the data which have been presented are not sufficient for definite conclusions, the results do

(*Cont. on p. 340*)

TABLE 5—EFFECT OF RADIATION ON MIL-L-6085A
(Low Volatility Aircraft Instrument Lubricating Oil)

SAMPLE NUMBER	TOTAL NEUTRON FLUX (10^{11} N/CM^2)	TOTAL GAMMA DOSE (10^6 ROENTGEN)	VISCOSITY @ −65°F, Cs	VISCOSITY @ 100°F, Cs	VISCOSITY @ 210°F, Cs	NEUTRALIZATION NUMBER	BROMINE NUMBER	POUR POINT (°F)
Control	0	0	5313.5	14.91	3.85	0.41	3.98	−100
Used Oil (No Irradiation)	0	0	5738.0	14.28	3.75	0.49	0.52	− 95
Used Oil	9.6	20	6094.5	15.03	4.00	2.03	2.09	−100

Development of Special Lubricants and Lubrication Practices For Small Apparatus

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Only by becoming thoroughly familiar with the functioning of any small piece of apparatus is it possible to intelligently determine the kind of lubrication the apparatus requires. With such a background, the lubrication engineer is able to determine the type of lubricant required and its method of application. The development of specialized lubricants and lubrication practices often extends life manyfold, obviates relubrication in service, or if relubrication is necessary, may greatly extend the periods between relubrications. Two typical pieces of telephone equipment are used for demonstration purposes, and the methods of approach explained.

Lubrication covers many fields of application from heavy equipment to watch or instrument parts. One of these fields is the small apparatus field represented by telephone and electronic equipment, small motors, gear trains, timing devices and many other small mechanisms.

By the development of specialized lubricants and lubrication practices, the life of such apparatus may be extended many fold, and often the initial lubrication be made satisfactory for life. Or if relubrication is necessary during service life, then the number of relubrications may be cut to a minimum and the process of relubrication often made easier and more effective.

In cases where apparatus is duplicated by the thousands or millions such as switches, teletypewriters, telephone dials, timing mechanisms, etc., the savings in initial costs due to extended life, and the savings due to reduced labor costs for maintenance, may be considerable, sometimes amounting to millions of dollars. In addition to the monetary savings involved, specialized lubrication obviates many service breakdowns and often permits apparatus to run smoother and quieter.

In order to specialize in lubrication, it is first of all necessary to become thoroughly familiar with the functioning of the apparatus and the service conditions encountered. This review is followed by an analysis of all wear points and any trouble conditions encountered in the past. With such a background of information, the requirements can be set, and measures taken to select and develop suitable lubricants.

For demonstration, two pieces of telephone equipment have been chosen, a dial which is subjected to heavy duty conditions by telephone operators, and a step-by-step switch used in telephone offices for switching calls from one subscriber to another. (The same approach can be just as well applied to any other piece of apparatus which justifies specialization.)

A No. 5 type dial, as shown in Fig. 1, is a spring mechanism wound up by hand and released under the control of a governor to furnish electrical pulses for operating associated relays and switches. It has a central shaft, brass gears, brass, bronze and steel bearings, pulsing cams and a governor—altogether 13 points to be lubricated. The tension of the spring is set and the governor adjusted to limit the speed to 10 ± 1 pulses per second at room temperature. Service conditions demand that the speed be controlled to these

Presented before the 13th Annual Meeting of the American Society of Lubrication Engineers, April 1958 at Cleveland, Ohio.

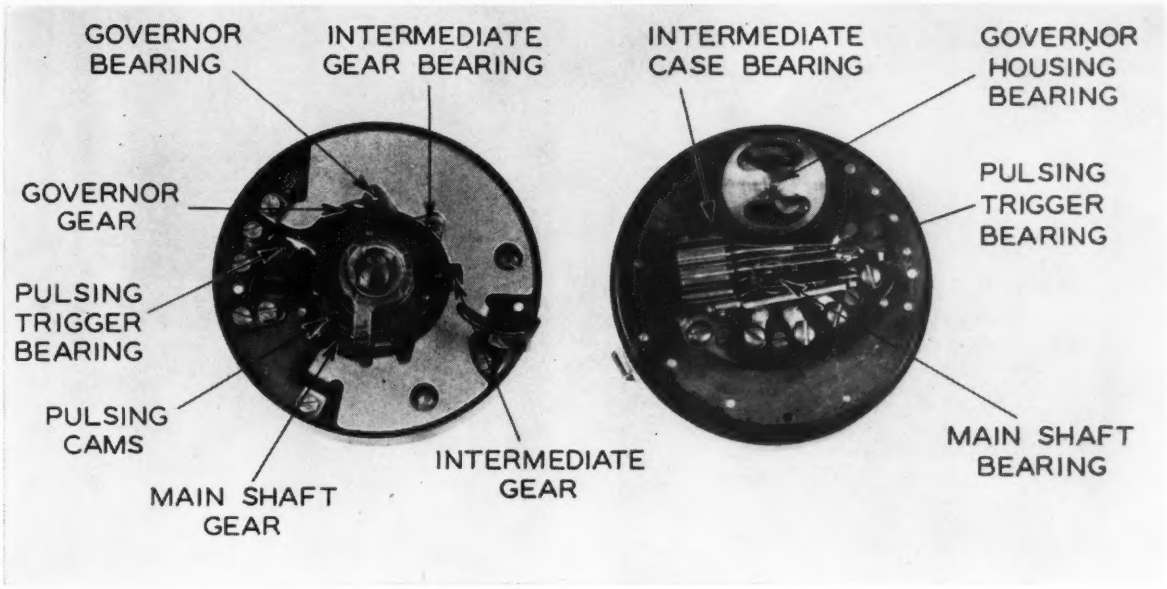


Fig. 1. Number 5 type operator's dial showing parts to be lubricated.

close limits. The dial is expected to operate for life without relubrication, under temperature conditions from +50 to 120F, in reasonably well-protected locations.

Examination of many dials which had failed mechanically indicated that worn-out gear teeth and bearings, particularly the teeth of the intermediate gear and its bearing, were the chief causes of wear failures. However, on preliminary tests it was found that if the bearing wear were reduced, impact on the gear teeth from rotation reversal was reduced considerably, and gear teeth wear was practically eliminated. In the lubrication of a piece of apparatus such as this containing many lubrication points, it is usually found that if care is taken of the first few important points, the same lubricant will be more than adequate for the rest of the points. In the case of the dial, the order in importance of the first few wear points is as follows:

1. Intermediate gear bearings.
2. Governor bearings.
3. Gears.

From a casual look at such a piece of apparatus without previous knowledge of the problems, most designers or engineers would recommend lubrication with an instrument or low viscosity oil. A review of past trouble conditions encountered on dials which had been lubricated with an oil having a viscosity of approximately 40 centistokes at 100F indicates that the chief causes of trouble are lack of lubricant, leakage of lubricant onto the governor braking surfaces, and rusting of the main bearing shaft.

With this background of information the functional requirements of the lubricant may be generalized as follows:

1. It must not materially change dial speed throughout the operating temperature range.
2. It must be sufficiently fluid to flow freely into the bearings.
3. It must leave no gummy deposits.
4. It must protect against corrosion.
5. It must not creep onto the friction surfaces of the governor.
6. It must prevent wearing of the parts and provide the maximum possible life.
7. It must provide smoother operation and reduce noise. The 40 centistoke oil used in the past may meet the first three of the above requirements, but it sadly fails to meet the other four. The lubricant determined to be most satisfactory was a semifluid product considerably more viscous, consisting of a base oil having a viscosity of approximately 240 centistokes at 100F and four per cent calcium soap.

Although the type of lubricant to be used is im-

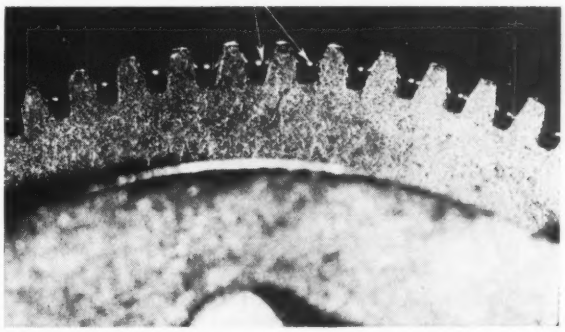


Fig. 2. Results of applying lubricant to dial gear teeth by special solvent dilution process.

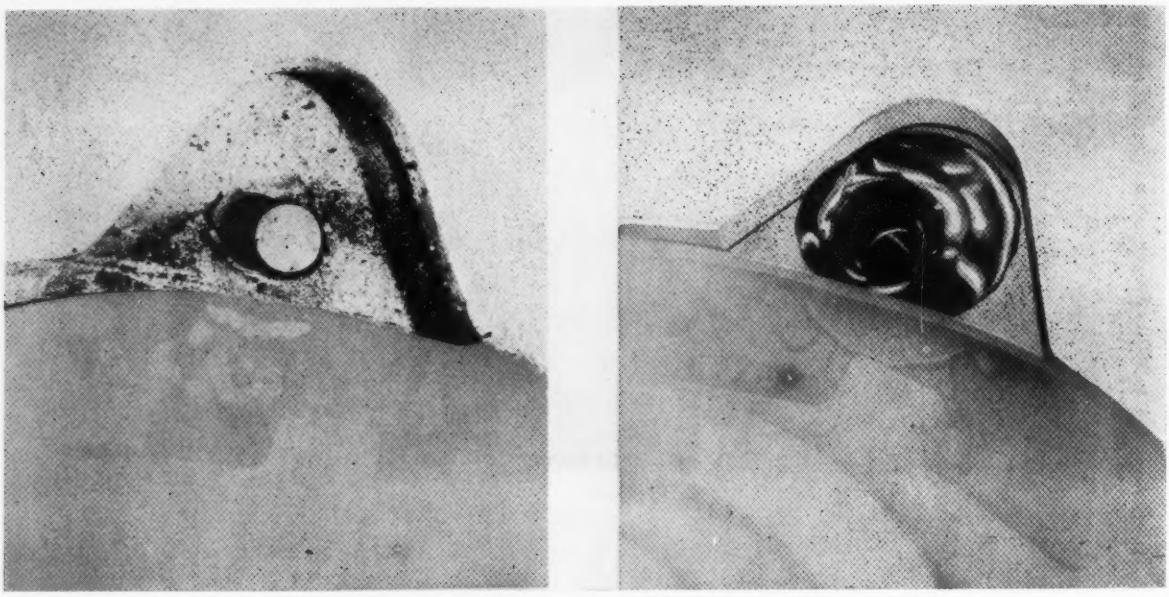


Fig. 3. Results of original and developed lubricants on dial bearings. Left-original oil after 500,000 operations. Note excessive wear of intermediate gear bearing. Right-viscous semi-fluid lubricant after 1,000,000 operations. Note pool of lubricant around bearing.

portant, its effectiveness is tied to how satisfactorily it can be applied in the right quantities to the places desired, and whether it will stay where intended.

Fig. 2 shows lubricant applied to the intermediate gear by means of a solvent dilution process—note the reservoirs of lubricant between the gear teeth which feed oil gradually to the tooth surfaces. Due to the quantity applied and the location of this viscous lubricant, it has little effect on dial speed. Fig. 3-A shows the intermediate gear bearing of a dial after it had been lubricated with the original oil and the dial operated 500,000 operations—note the excessive wear. Fig. 3-B shows the intermediate gear bearing of a dial after it had been lubricated with the more viscous semi-fluid product and the dial operated 1,000,000 operations. Note the pool of lubricant around the bearing. The wear in this case was negligible. The application process consisted of applying a carefully controlled quantity of the lubricant to the bearing with a special tool which could be used on the assembly line. After a few operations of the dial, a part of the lubricant worked its way down into the bearing, and the remaining lubricant served as a reservoir to replenish it continually. The viscous semi-fluid product had little effect on the speed of the dial because of the method of application to the gears and because of the small part of total torque absorbed by the bearings. This is an excellent example for demonstrating the importance of using the right lubricant and of applying it in the right quantity, in the right place, at the right time. Each one of these aspects is essential.

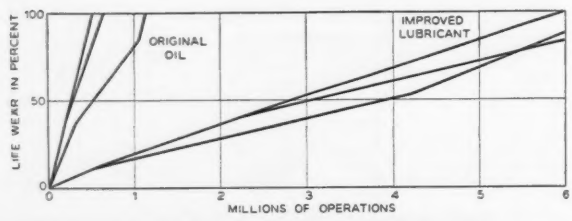


Fig. 4. Extended dial life possible with improved lubricants.

Fig. 4 shows the results of dial life tests using the two different lubricants. Dials lubricated with the original oil operated satisfactorily for approximately 500,000 operations, while dials lubricated with the improved lubricant increased the life approximately tenfold. Also with the improved lubricant, the dials operated more smoothly and from two to five decibels more quietly.

LUBRICATION OF STEP-BY-STEP SWITCHES

A step-by-step switch as shown in Fig. 5 is an electrical and mechanical mechanism which operates under the control of electrical pulses and switches contacts to desired locations. The switch may step up to any one of 10 levels and step around to any one of 10 different locations by the associated number of pulses. It returns to its normal horizontal position by means of a spring and to its normal vertical position by gravity. Most of the wear points (23 in all) are marked in Fig. 5. They consist of a main shaft and bearings, vertical and horizontal ratchets, vertical and horizontal pawls, sleeve bearings and many small bearing surfaces.

The approach to the lubrication of a step-by-step switch differs in many respects to the approach taken in the lubrication of the No. 5 type dial. First of all, the switch is expected to last for forty years

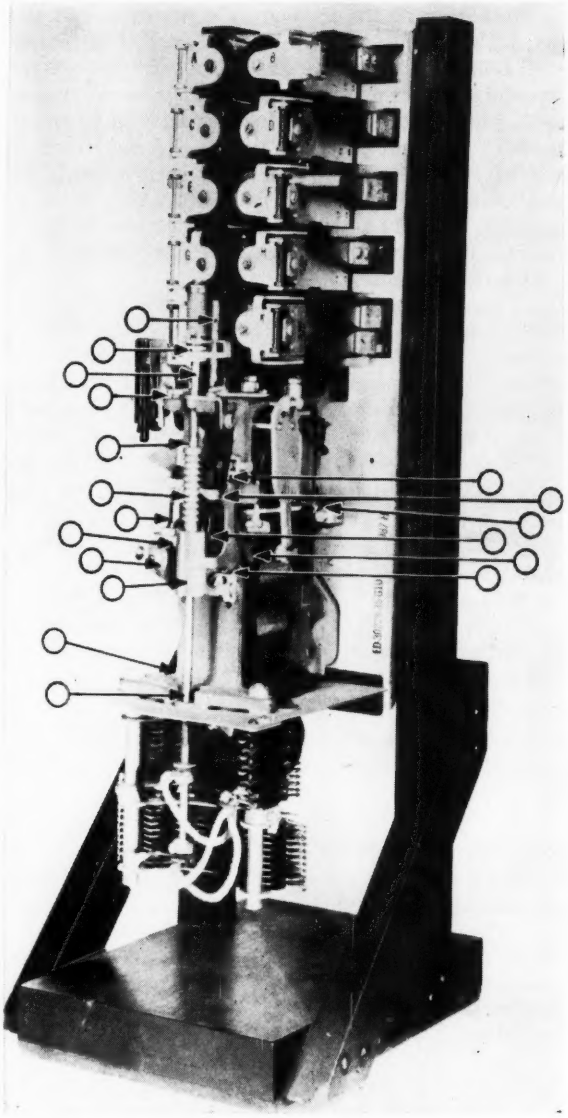


Fig. 5. Telephone step-by-step switch showing some of the lubricating points.

and no lubricant can be expected to last that long. Secondly, wear is not a serious factor in the switch, but keeping some lubricant on certain parts is essential. The dial will satisfactorily run dry for a while, but the switch if allowed to become dry will soon cause trouble. This makes it mandatory to lubricate the switches periodically in service.

In the case of the dial, the savings and benefits involved are due to the initial lubrication extending the life of the apparatus, thereby obviating replacements with new dials and the temporary trouble conditions developed by the malfunctioning of worn out dials. In the case of the switch, the major savings involved are due to cutting the number of relubrications to a minimum and making the process of relubrication as easy as possible, thereby reducing labor costs.

The switches operate within a temperature rang of 10 to 160F in reasonably well-protected locations. The order of importance in the lubrication of the switch parts is as follows:

1. Main shaft bearings
2. Vertical pawl
3. Shaft extension sleeve
4. Normal post

A review of past mechanical trouble conditions which were encountered indicates that the principal ones were failure of the switch to return to normal due to a dry main shaft, sticking vertical pawls, wear of the shaft extension sleeve, and splashing of the lubricant from the main shaft bearing when the switch returned to normal.

The functional requirements of the step-by-step switch lubricant are:

1. It must permit the switch to return to normal in less than .3 of a second under the worst service and temperature conditions.
2. It will not cause gumming or sticking of the pawls.
3. It must be sufficiently viscous or tacky to prevent dripping down the shaft onto the electrical connections.
4. It must be sufficiently viscous or tacky such that it will not splash when the shaft drops from the top level.
5. It must reduce wear to a minimum.
6. It must be easy to apply with suitable tools.
7. It must be reasonably visible so that inspection will easily reveal whether or not the switch is lubricated.
8. It must operate satisfactorily for the maximum length of time possible without relubricating.

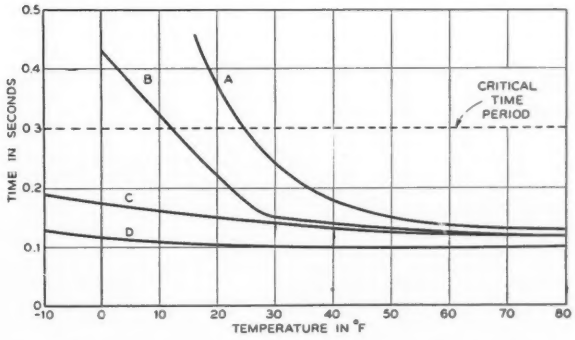


Fig. 6. Time taken for switches to return to normal at various temperatures using different lubricants.

Some of the information pertinent to the job, obtained in the laboratories, is shown in Fig. 6, 7 and 8. Fig. 6 shows the time taken for a switch to return to normal after release, when lubricated with various lubricants. Service requirements demand that the switch return in less than 0.3 seconds. It will be noted

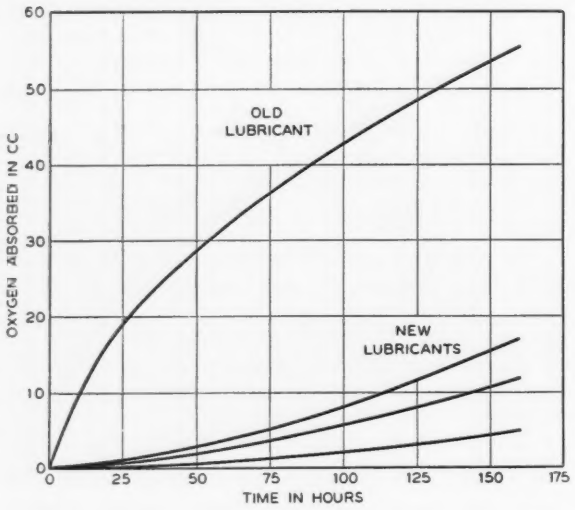


Fig. 7. Improved oxidation stability possible with improved lubricants.

that lubricant *A* is satisfactory only down to 25F, lubricant *B* to 12F and lubricants *C* and *D* to temperatures much lower. Fig. 7 shows oxygen absorbtion tests on the old lubricant *A* and three promising new ones. This test has been found to correlate closely with oxidation and gumming of the lubricant in service. Lubricant *A* oxidizes rapidly and soon causes sticking of the switch pawls in service. Fig. 8 shows spreading tests of the old lubricant and some of the new ones tested. Excessive spreading may cause creepage onto electrical contacts and will leave less lubricant in the right place. The above information and a great deal more can be developed in the laboratory before costly life tests on the apparatus need be made.

Referring to the method of application and the ease with which relubrication can be carried out, it has been found that in many cases this warrants careful consideration, even to the extent of developing special tools, which will assure the right quantity of lubricant reaching the right place. In the case of the switch, a small No. 4 camel's hair brush has been found to be most suitable. By means of the brush a film of lubricant can be easily applied to the ratchet surfaces, and reasonably controlled quantities applied speedily to the many other parts.

Final tests of step-by-step switches carried out under field conditions, indicated that the relubricating period of six months using the old lubricant, could be extended to two years with the new, thereby eliminating three relubrications every two years. Considering a man lubricates switches at the rate of twelve per hour, and there are approximately six million switches in service involving $\frac{6,000,000}{12} = 500{,}000$ man hours each time they are relubricated, the savings involved are considerable and well warrants specialization.

These savings may be unusual, but the technique of developing the right lubricant to suit the apparatus and its conditions and of recognizing the extreme importance of the other three R's of lubrication, can be applied to many other things with surprising success.

SUMMARY

By a careful analysis of the functioning of a piece of apparatus, the principal wear points and the reasons why it first of all fails, it is often possible to develop suitable lubricants which, when applied in proper quantities in the proper places, will extend life manyfold or considerably extend the periods between relubrications.

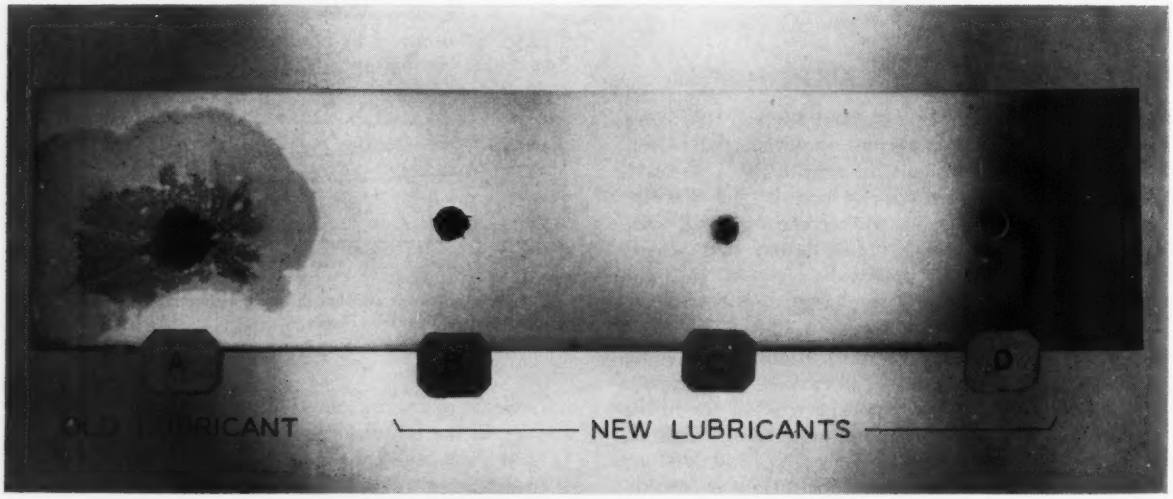
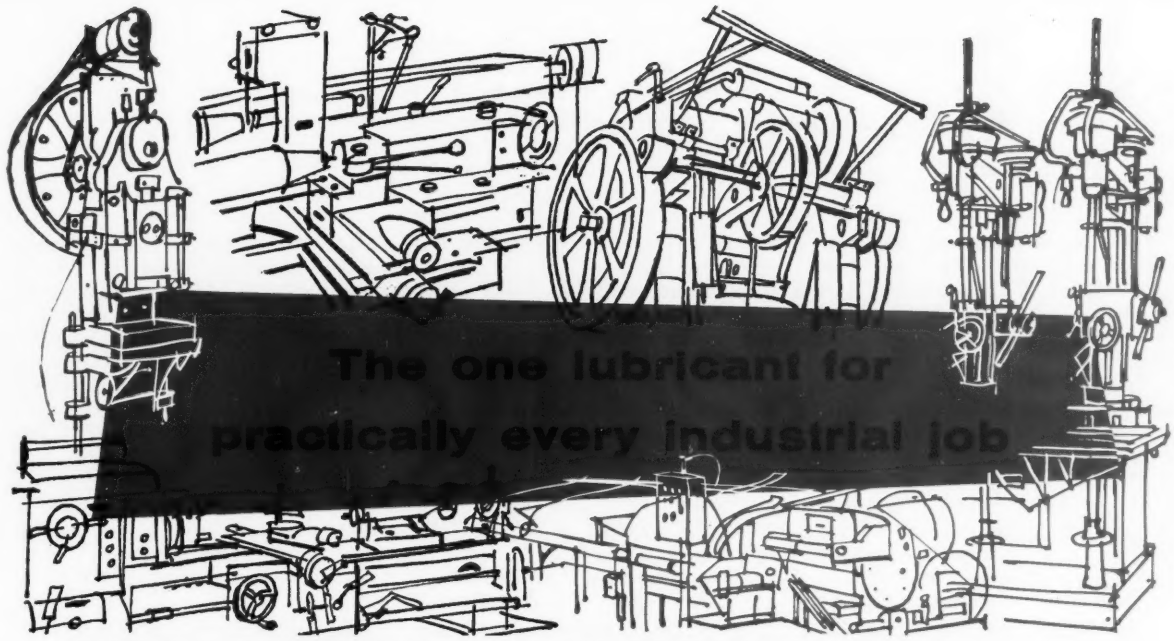


Fig. 8. Typical spreading tests on step-by-step switch lubricants. Condition after one week at 160F.



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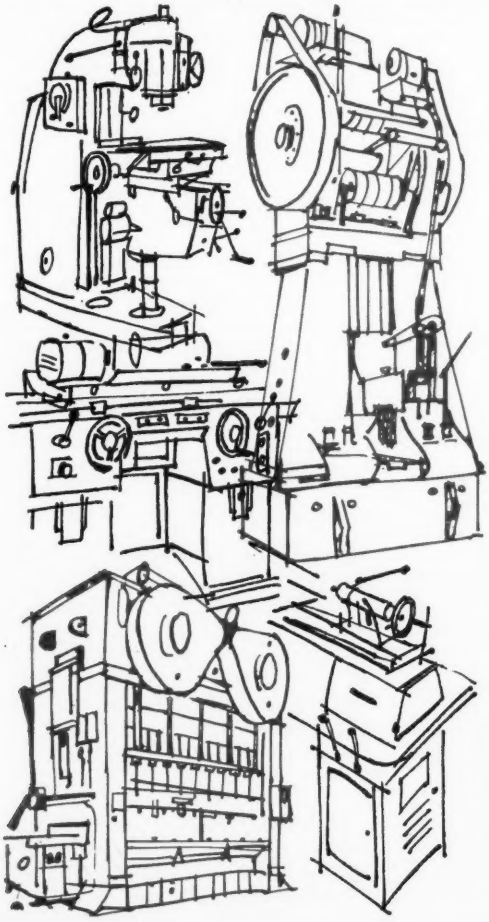

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Patent Abstracts

Compiled by Ann Burchick
Aluminum Co. of America

Method of Grease Manufacture with Combined Oil Quench and Recycle Cooling, Patent #2,876,198 (R. C. Givens and H. J. Pitman, assignors to The Texas Co.) The method of grease manufacture which comprises providing a molten homogeneous mixture of a lithium hydroxy fatty acid soap and an oleaginous liquid in grease forming proportions at an elevated temperature above the melting point of the soap, and controlling the crystallization of the said soap during cooling by continuously withdrawing a stream of relatively small volume from a maintained agitated body of the said mixture and passing the said stream through an external cooler back to the said maintained body of the mixture while the said mixture is cooled from a temperature above the melting point of the soap to a temperature below the melting point of the soap and until substantial gelling has occurred, and simultaneously quenching the said mixture at a temperature above the melting point of the soap by introducing a relatively cool oil comprising a minor proportion of the total oleaginous component of the finished grease.

Lubricants, Patent #2,876,199 (J. I. Wasson and W. C. Howell, Jr., assignors to Esso Research & Engineering Co.) An improved open gear lubricant having a viscosity of 1,000 to 6,000 sus at 210F consisting essentially of a blend of from about 40 to 60 wt per cent of an asphaltic material selected from the group consisting of reduced and oxidized asphalts with about 60 to 30 wt per cent of a highly aromatic solvent extract oil, said extract oil having a viscosity of 210F of about 60-360 sus, a viscosity index of from about −40 to −330 and an aniline point between about 90 and 120F, percentages being by weight based on the weight of the total composition.

Multifunctional Lubricant Additives, Patent #2,876,213 (J. H. Bartlett and W. C. Hollyday, assignors to Esso Research & Engineering Co.) An oil soluble polymer of an unsaturated ester, said polymer having the property of reducing the pour point of a phenol extracted Mid-Continent distillate having a viscosity at 210F of 45.6 sus and a viscosity index of 100 by at least 5F in 0.05 per cent concentration therein.

Stabilized Calcium Fatty Acid Base Grease, Patent #2,877,181 (J. P. Dilworth, K. Uhrig, and H. C. Becker, assignors to The Texas Co.) A stable anhydrous calcium grease comprising an oleaginous lubricating base as the major component, a calcium salt of a C_{12} to C_{24} unsubstituted fatty acid as the thickening agent and 0.5 to 3 weight per cent of a compound selected from the group consisting of an estolide of a hydroxy fatty acid containing 12 to 24 carbon atoms, a calcium salt of said estolide and a mixture thereof, said estolide having an average molecular weight between 500 and 3500, said grease having been shock cooled from a temperature of 190 to about 100F.

Organosilicon Lubricants, Patent #2,877,182 (J. J. May, assignor to Dow Corning Corp.) As a composition of matter a mixture consisting essentially of (a) a fluid organopolysiloxane and (b) 0.25 to 5 per cent by weight based on the siloxane of a halogenated fatty acid of 1 to 12 carbon atoms.

Method of Preparing Neutral Oils, Patent #2,878,181 (G. W. Ayers and W. A. Krewer, assignors to The Pure Oil Co.) The process of preparing petroleum oils of low neutralization number which comprises treating said petroleum oil with a basic nitrogen compound capable of amide formation in the presence of N, N'-dicyclohexylcarbodimide and separating the oil phase from the reaction products.

Hydrocarbon Resistant Glycerol Base Lubricant, Patent #2,878,184 (W. A. March, assignor to Rockwell Manufacturing Co.) A plug valve lubricant and sealant composition made from ingredients comprising substantially the following:

Ingredient:	*Percentage Range (Wt)*
Glycerol	78-79
Sodium carboxymethylcellulose	7-3
Water soluble vegetable gum powder	2-1
Sodium stearate	2-1
Detergent wetting agent	4-2
Starch	2-1
Animal glue	3-1
Sodium glyceroxide	0.75-3.75

Filter Aid for Preparing Dispersions in Lubricating Oil, Patent #2,878,185 (G. L. Weamer, assignor to California Research Corp.) In the process of preparing dispersions of alkaline earth metal glycoxides in lubricating oils by forming an admixture of a lubricating oil, a dihydric alcohol containing less than five carbon atoms, from 0.02 per cent to 7.0 per cent, by weight, based on the oxide, of an inorganic substance selected from the group consisting of alkaline earth metal oxides and hydroxides, and from 0.1 per cent to 10 per cent by weight of an alkaline earth metal sulfonate, heating said admixture to a temperature in the range of about 175F to about 400F, removing unreacted dihydric alcohol by distillation, and filtering said admixture, the improvement comprising blending into said lubricating oil composition prior to filtration, an alkyl phenol having no more than three alkyl groups attached to the benzene nucleus, each alkyl group containing from 4 to 30 carbon atoms, and wherein the mole ratio of said alkyl phenol to said inorganic substance has a value from about 0.1 to about 1.5, wherein the weight ratio of dihydric alcohol to said inorganic substance is from 30:1 to 10:1, and wherein the mole ratio of said metal inorganic substance to said sulfonate has a value from about 1.75 to about 4.0.

Grease Composition Containing Sodium and/or Lithium Soaps of Low, Intermediate and High Molecular Weight Acids, Together with Glycerine or Related Hydroxy-Compounds, Patent #2,878,186 (C. Liddy, assignor to Socony Mobil Oil Co., Inc.) A grease composition comprising: an oil vehicle, from about one to about five per cent by weight of a low molecular weight polyhydroxy alcohol, and a mixture therewith of alkali metal soaps and salts selected from the group consisting of lithium and sodium soaps and salts and of mixtures of said soaps and salts, the mixture of said soaps and salts being present in a grease forming quantity, and the alkali metal soaps and salts of said mixture being soaps and salts of acids identified as (I), (II) and (III), one of said acids being a low molecular weight unsubstituted straight chain saturated monocarboxylic acid (I) having from one to six carbon atoms per molecule, one of said acids being an intermediate molecular weight unsubstituted saturated monocarboxylic acid (II) having from seven to twelve carbon atoms per molecule and having no side chain larger than a methyl group, and one of said acids (III) having more than twelve carbon atoms per molecule and having no more than one unsaturated double bond being selected from the group consisting of a monocarboxylic acid and a monohydroxy-substituted monocarboxylic acid, the per cent-by-weight distribution of said acids being

as follows:

I. From about 10 to about 50.
II. From about 30 to about 70.
III. From about 10 to about 50.

Grease Composition Containing Alkali Metal Salts and Soaps of Intermediate Molecular Weight Acids and of Low Molecular Weight Acids, Patent #2,878,187 (C. Liddy, assignor to Socony Mobil Oil Co., Inc.) A grease composition comprising: an oil vehicle, a mixture of an alkali metal salt and an alkali metal soap, and from about two to about five per cent by weight of a low molecular weight polyhydroxy alcohol, the mixture of salt and soap being present in a grease forming quantity, and the alkali metal salt of said mixture being a salt of a low molecular weight unsubstituted straight chain saturated monocarboxylic acid (I) having from one to six carbon atoms per molecule, and the alkali metal soap of said mixture being a soap of an intermediate molecular weight unsubstituted saturated monocarboxylic acid (II) having from seven to twelve carbon atoms per molecule and having no side chain larger than a methyl group, the molar ratio of said acid (I) to said acid (II) being from about 0.25:1 to about 10:1.

Method for Producing a Lubricating Oil, Patent #2,879,223 (E. L. Cole, W. E. Skelton and R. K. Meyers, assignors to The Texas Co.) A method for producing a lubricating oil characterized by a low carbon residue and low solid point which comprises alkylating a cycle gas oil extract with olefinic material within the molecular weight range of naphtha to gas oil olefins to produce an alkylated extract characterized by a high solid point, a high carbon residue and a low viscosity index, and thereafter subjecting the alkylated extract to hydrorefining at a temperature in the range of from 500 to 800F and at a pressure in the range of from 500 to 5000 psig.

Clay-Thickened Lubricants and the Preparation Thereof, Patent #2,879,229 (C. A. Stratton, assignor to Phillips Petroleum Co.) A bodied lubricant consisting essentially of hydrocarbon lubricating oil; organophilic bentonite in a proportion sufficient to thicken said oil to grease consistency, said bentonite having been rendered organophilic by replacing the exchangeable inorganic cations of the bentonite with organic cations from salts of organic compounds selected from the group consisting of amines, polyamines and quaternary ammonium compounds; and about 0.5 to 3 weight per cent dispersion agent of acetone and a compound selected from the group consisting of acetonitrile and propionitrile, said dispersion agent being about 1.5 to about 35 weight per cent nitrile and the remainder acetone.

Motor Lubricating Oil Composition, Patent #2,879,236 (S. R. Newman, R. Y. Heisler, and K. L. Dille and N. Alpert, assignors to The Texas Co.) A lubricating oil containing a minor amount of a polyglycol carbamate.

Soap-Salt Complex Thickened Greases, Patent #2,880,174 (A. J. Morway and H. K. Wiese, assignors to Esso Research & Engineering Co.) A lubricating grease composition comprising a major portion of a lubricating oil and a minor grease-making proportion of a soap-salt complex consisting of at least one alkaline earth metal soap of a high molecular weight fatty acid having from about 18 to 22 carbon atoms per molecule, an alkaline earth metal salt of a polycarboxylic acid material selected from the group consisting of dicyclodiene dicarboxylic acid and tricarboxylated bicyclo (2,2,1)-heptene, and an alkaline earth metal salt of acetic acid, in which the mol ratio of acetic acid to the other carboxylic acids is about 4:1 to 40:1 and a mol ratio of polycarboxylic acid material to high molecular weight fatty acid is about 0.5:1 to 5:1.

Lubricating Oil Additive Compatibility Improver, Patent #2,880,175 (A. E. Michaels and Niilo V. Hakala, assignors to Esso Research & Engineering Co.) A nonturbid lubricating oil blend having a high viscosity index and exhibiting a high degree of detergency consisting essentially of a blend of a mineral oil base stock having combined therein about 0.05 per cent to about 10.0 per cent by weight of a copolymer of a fumarate ester containing from about 8 to 18 carbon atoms in the ester portion thereof and vinyl acetate, from about 0.2 per cent to about 3.0 per cent by weight of a metal salt of an alkylated phenol as a detergent inhibitor, and from about 0.01 per cent to about 1.0 per cent by weight of a compatibility improver of the class consisting of diethylene glycol monoethyl ether, methoxy triglycol, and dimethoxy tetraethylene glycol.

Lubricating Grease Comprising Methylchlorophenyl Silicone Polymer Thickened with a High Melting Diazo Compound, Patent #2,880,176 (J. R. Roach and J. P. Dilworth, assignors to The Texas Co.) A lubricating grease consisting essentially of a methylchlorophenyl silcone polymer oil of lubricating characteristics thickened to a grease consistency.

Lubricating Greases Thickened with Benzidene Diazo Compounds, Patent #2,880,177 (J. F. Lyons, P. R. Thomas and N. R. Odell, assignors to The Texas Co.) A lubricating grease consisting essentially of a lubricating oil thickened to a grease consistency.

Rust Inhibiting Composition, Patent #2,881,140 (R. W. Schrum, assignor to Sinclair Refining Co.) A composition consisting essentially of about 50 to 95 per cent of an aromatic hydrocarbon solvent, about 5 to 65 weight per cent of an oxidate of a foots oil fraction and about 0.1 to 4 weight per cent of a substantially dehydrated partially oxidized microcrystalline wax having a saponification number of about 10 to 150, said foots oil oxidate having a melting point of about 80 to 95F, an API gravity of about 10 to 25 and a saponification number of about 200 to 325.

Metal Working Lubricants, Patent #2,882,228 (F. J. Watson and J. E. Weigel and F. C. Younger, assignors to Shell Development Co.) A lubricating oil composition comprising a major amount of a mineral lubricating oil containing from about 0.1 per cent to about 10 per cent each of a long chain highly branched primary tertiary aliphatic amine of at least eight carbon atoms salt of a chloromethanephosphonic acid, and a partial ester of a polyhydric alcohol having from two to six carbon atoms and a C_{10}-C_{20} fatty acid.

Lubricant Compositions, Patent #2,882,229 (E. E. Richardson, assignor to Standard Oil Co.) A lubricating oil composition comprising a major proportion of a mineral lubricating oil, between about 0.002 and 10 per cent of an alkaline earth containing neutralized reaction product of a phosphorus sulfide and an olefin polymer, between about 0.001 and 5.0 per cent of the polymerization products of unsaturated fatty acids having from 16 to 26 carbon atoms, said polymerization products having a molecular weight between 400 and 2000, and between about 0.001 and 5.0 per cent of an oil soluble organic sulfur compound selected from the class consisting of aliphatic mercaptans having from 8 to 16 carbon atoms and aliphatic disulfides having from 15 to 30 carbon atoms.

Lubricating Greases Containing Alkyl-Beta-Amino Propionates, Patent #2,882,230 (J. H. Bartlett and A. J. Morway, assignors to Esso Research & Engineering Co.) A lubricant comprising a major proportion of a lubricating oil and in the range of 10 to 40 weight per cent of a complex thickener consisting of significant amounts of: (1) a metal salt of a carboxylic acid having in the range of one to five carbon atoms per molecule, (2) a metal soap of a fatty acid having in the range of 10 to 30 carbon atoms per molecule, and (3) a metal soap of an alkyl-beta-amino propionic acid, the alkyl group thereof having in the range of 10 to 30 carbon atoms; the metal component of said soaps and salt being selected from the group consisting of alkali and alkaline earth metals, the propionic acid soap constituting in the range of 20 to 75 weight per cent of said complex thickener and the molar proportion of said salt to said soaps being in the range of one to three.

Needle Oil, Patent #2,882,231 (E. W. Brennan and J. N. Bowden, assignors to The Pure Oil Co.) A compounded knit-

(*Cont. on p. 336*)

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PATENT ABSTRACTS

(*Cont. from p. 335*)

ting needle oil especially adaptable for use in the lubrication of machine-operated knitting needles in the knitting of yarn or thread pretreated with a polyvinyl alcohol-containing size into fabric, said oil consisting of a major portion of a petroleum oil having a viscosity of about 65-150 sus at 100F and small portions of (1) an oil-soluble rust inhibitor in an amount sufficient to inhibit the moisture rusting of said needles, (2) an oil soluble, non-ionic surface active agent in an amount sufficient to reduce the interfacial tension of the compounded oil to less than about 10 dynes/cm, and (3) about 0.5-50 per cent by weight, based on total composition, of an oil-soluble, ester plasticizer for polyvinyl compounds selected from the group consisting of esters of phthalic acid containing no alkoxy substituent of more than ten carbon atoms, to prevent the accumulation of said size on said knitting needles.

Polyethylene-Wax Composition and Process of Blending Same, Patent #2,882,246 (G. T. Leatherman and C. V. Detter, assignors to Phillips Petroleum Co.) A composition comprising a major proportion of a wax having a melting point of at least 100F, selected from the group consisting of paraffin wax, candelilla wax, carnauba wax, montan wax and spermaceti wax, and from 0.1 to 10 per cent by weight of a solid polyethylene produced by polymerizing ethylene in the presence of a catalyst consisting of chromium oxide, containing hexavalent chromium supported on at least one oxide selected from the group consisting of silica and alumina, said polyethylene having a density in the range of 0.92 to 0.97 and a melting point in the range of 235 to 260F.

Lubricant Compositions, Patent #2,883,339 (E. E. Richardson, assignor to Standard Oil Co.) A lubricating oil composition comprising a major proportion of a mineral lubricating oil base, between about 0.002 and 10 per cent of an alkaline earth-containing neutralized reaction product of a phosphorus sulfide and an olefin polymer, between about 0.001 and 5 per cent of the polymerization products of unsaturated fatty acids having from 16 to 26 carbon atoms, said polymerization products having a molecular weight between about 400 and 2000, and between about 0.001 and 5 per cent of an oil soluble phenol selected from the group consisting of alkylated monohydric phenols and alkylated dihydric phenols.

High Viscosity Index Detergent Lubricating Oils, Patent #2,883,340 (W. L. Wasley and C. E. Wilson, assignors to Union Oil Co. of California) A high V.I., detergent lubricating oil consisting essentially of mineral lubricating oil containing between about 1 per cent and about 15 per cent by weight of the metal salt of a hydrocarbon polymer sulfonic acid, said metal being selected from the class consisting of the alkali and alkaline earth metals and said hydrocarbon polymer being one having a molecular weight between about 10,000 and about 50,000 and selected from the class consisting of polymers of monoolefins having three to six carbon atoms per molecule and copolymers of said monoolefins with multiolefins having four to seven carbon atoms per molecule in which the ratio of multiolefin to monoolefin is between about 0.005 and about 0.1 to 1.

Lithium Base Grease Modified with Lithium or Aluminum 2-Ethyl Hexanoate, Patent #2,883,341 (J. R. Allison, assigner to Leffingwell Chemical Co.) A bleed-resistant lubricating grease comprising lubricating oil and a soap component consisting essentially of a lithium soap and a second soap of the group consisting of lithium 2-ethyl hexanoate and aluminum 2-ethyl hexanoate, said second soap constituting between ½ per cent to 20 per cent of said soap component, said second soap acting to reduce substantially the low temperature bleeding tendencies of the grease as compared with those of a corresponding grease lacking said second soap.

Extreme Pressure Lubricant, Patent #2,885,-363 (G. Wolfram and J. B. Stucker, assignors to The Pure Oil Co.) The preparation of an extreme pressure lubricant additive having improved storage stability and low temperature charactertics when blended with solvent refined mineral lubricating oil from natural fatty material having a content of polyunsaturated glyceryl esters of high boiling fatty acids exceeding about 10 per cent, which esters when chemically reacted with sulfur and phosphorus tend to form sulfur and phosphorus-containing reaction products insoluble in said lubricating oil, comprising reducing the content of said polyunsaturated glyceryl esters to about 1.0 to 2.0 weight per cent, then sulfurizing and phosphorizing said material during mechanical agitation without blowing with an oxidizing medium under conditions of time and temperature such that a product having a viscosity below about 400 sus at 210F is produced.

Paper-Machine Oils, Patent #2,885,362 (J. N. Bowden and E. W. Brennan, assignors to The Pure Oil Co.) A paper-machine oil composition consisting of a mineral oil base, about 0.5 to 2.0 weight per cent of barium diisobutylhydroxyphenyl sulfide, about 0.5 to 2.0 weight per cent of zinc dioctyldithiophosphate and about 0.05 to 0.20 weight per cent of an alkaline earth metal petroleum sulfonate, said composition being characterized by its ability to pass the dynamic demulsibility test.

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ASLE Technical Digest

Papers which, because of space limitations, cannot be published in full in Lubrication Engineering or ASLE Transactions.

"The Lubrication of Railway Journal Roller Bearings," by P. C. Paterson, Timken Roller Bearing Co., Canton, Ohio, ASLE-SAE Joint Automotive Lubrication Conference, March 1958.

The recent wide spread increase in the application of roller bearings to certain phases of railway service has been encouraged by the useful road service performance data obtainable on bearings, seals and lubricants under varying conditions of load, speed and climate which cannot be demonstrated by laboratory or other methods. These data have been equally as valuable to the manufacturer of lubricants as to the bearing designer and railway people, in pinpointing the benefits to be derived from a bearing in which (a) pre-lubrication at time of assembly is practicable; (b) all parts are interchangeable; (c) no adjustment is necessary when bearing assembly is applied to the axle; (d) housing designed for either oil or grease. The author's review of past experience leading up to the present acceptability of grease lubrication is interesting.

While the all year grade of car oil has been successfully retained by annular groove and flinger design of enclosure without any oil additions between the 30 day inspection periods in fast main line passenger service, in freight service where cars might be away from the owning lines for months or even years, it could be unsuitable. Oil drain off from the surfaces of the rolling elements during idle periods or even actual oil loss from the enclosures could be too serious. Steadily increasing costs of frequent oil level inspections was an additional reason for considering re-introduction of grease lubrication. This was further encouraged as a means of improving the performance of other enclosure designs whose oil retention characteristics were limited by increased clearances necessary to compensate for lateral, or angular displacement of the bearing applications.

Subsequent 90 day inspections of the grease, by removing the bearing housing covers showed no grease loss. In some cases it was even found possible to operate over 250,000 miles to wheel renewal without addition of grease, in roller bearing housings which had previously operated on oil lubrication. In other words, the ultimate objective in the operation of a railway journal roller bearing was attained: the ability to schedule the relubrication period with other phases of maintenance work.

The recommended quantity of grease is a factor in obtaining extended road performance. This should not be exceeded, otherwise overheating due to churning could result, with reduced consistency and possibility of leakage. Continuous high temperature operation also can impair the lubricating properties of the grease. Obviously the severity of railway roller bearing service requires a grease of very positive characteristics: (a) It must remain chemically and physically stable. (b) It must not thin down in service, nor stiffen to the point of channeling. (c) Pumpability must be good especially at low temperatures. (d) It must be operable over a wide range of temperatures. (e) Compatibility with other greases must be satisfactory. (f) And finally, it must be highly resistant to water and oxidation. AAR Specification M-917-53 relates to these conditions. A companion specification for bearings requires design for periodic grease lubrication at three year intervals. (*Digested by A. F. Brewer*)

"Limited Slip Differentials," by L. J. O'Brien, Dana Corp., Fort Wayne, Ind., ASLE Gear Symposium, Jan. 1959.

A differential is required in the automotive vehicle for a number of reasons:

(a) To prevent the transfer of full engine torque to one axle shaft.
(b) Because more than one driving wheel is used, and these driving wheels must not interfere with handling of the vehicle.
(c) Because all wheels of the vehicle do not travel the same distance in the same length of time.

These are functions of the conventional differential which, however, has a definite disadvantage in that it divides the power equally to both wheels with tendency to drive the wheel easiest to turn. Furthermore, under certain conditions there may be uncontrolled load application at the driving wheels; i.e. spinning of the wheel with poor traction. In the modern high performance automobile this can present a safety hazard by affecting the stability and control of the vehicle when this wheel regains traction under the magnitude of the force applied.

The limited slip differential is designed to reduce this hazard. In addition to providing the essential requirements as listed above, it provides sufficient traction torque to the non-spinning wheel under all conditions of vehicle operation so that the driving force is under complete control of the driver at all times. In reporting on the studies incident to development of the limited slip differential, the author emphasizes that long life, efficient functioning regardless of wear, acceptable size and weight commensurate with riding ability of the vehicle, reasonable cost and quietness in operation are other economic factors which had to be considered.

Division of load is the basic operating difference between these types of differentials. Since the conventional differential divides the load equally between the driving wheels, the load at the slipping wheel is multiplied by one, and applied to the wheel with traction. The limited slip differential is a similar load divider except that the load at the slipping wheel can be multiplied by some numerical value. As the power is increased in the automotive vehicle obviously more traction is needed to use this power.

The major problem in the development and application of the limited slip differential has been lubrication, as related to reduction of noise as indicated by chatter. The friction surfaces do not slide smoothly at very slow speed as a result of the difference between the starting and running torque. Here higher coefficient of friction in the lubricant is beneficial. (*Digested by A. F. Brewer*)

"Lubrication of Missiles and Military Aircraft," by J. E. Parkin, Chance-Vought Aircraft Co., Dallas, Texas, ASLE Annual Meeting Paper, April 1958.

Lubricants for the various component mechanisms in missiles and military aircraft are studied from viewpoints broadly classified as environmental or operating. In either case they must function in highly complex lubrication arrangements such as the intricate electronic guidance systems in guided missiles which utilize special low volatility-type lubricants. Temperature is a vital factor. In environmental consideration the climate is involved, varying from arctic to desert. This relates to storage as missiles may have to be stored for extended periods in polar regions where temperatures as low as −65F could prevail. Conversely in desert installations all lubricated mechanisms must be able to withstand much higher storage temperatures and at the same time be so sealed as to be protected against entry of dust. Lubricants to be acceptable must be functional, therefore, through a range of −65F to 150F.

Temperature associated with altitude relates to the operating phase of the problem. As a rule there is an excess of heat, as it may develop (1) from the aircraft's power plant through conduction and radiation; or (2) from the friction of the aircraft as it moves through the atmosphere. To be applicable in modern fighter aircraft, lubricants must perform adequately within a temperature range of −65F to 300F or in special cases to 500F. A good example of an extreme would be the horizontal tail bearings which, being located very close to the engine blast, are among the hottest lubricated parts on the aircraft. Conduction and radiation of skin temperatures to certain of the lubricated components results from flying friction. Increase in flying speed adds to the temperature problem. Here aerodynamic study of materials for use at higher speeds and higher temperatures is required. When such structural materials are found, it follows that lubricants will have to be developed to permit their use.

In deciding upon a specific lubricant for such service, evolution and past history are important sources for study. Missiles can well be used to test lubricants for aircraft because they fly faster than the latter. Accordingly when recoverable guided missiles are used their value as proving grounds is apparent. Performance ability coupled with the usual chemical and physical laboratory tests of both new and recovered products are valuable screening indications of how effectually the mechanisms are being, or can be protected in flight. But flight testing can be only the beginning, because of replacements and changes. Electronic components may need replacing or new equipment is sometimes added. Lubricants for such equipment must be used sparingly; furthermore they have to be low volatility type and able to maintain their stability at high temperatures. Miniaturization of components to reduce weight adds to the problem because as size is reduced viscosity may have to be lowered.

Unlike lubricants for other industries, those for aircraft service at present are composed of unfamiliar chemicals. Fighter aircraft lubricants are essentially synthetic oils plus additives. These latter include antioxidants, inhibitors and thickeners. Antioxidants minimize oxidation at higher temperatures; inhibitors such as petroleum sulfonates are usually stabilizers; thickeners are included in carefully controlled amounts to impart body to the lubricant. (*Digested by A. F. Brewer*)

"A Recent Advancement in the Development of Extreme Pressure Greases," by A. I. Sippola, ASLE Annual Meeting Paper, April 1958.

Research development and formulation of the manufacturing procedure for any distinctive type of petroleum base lubricant is one of the most challenging projects confronting the petroleum chemist. He must couple his available knowledge of additives and their compatibility with study of the service conditions under which the product must function. Today these conditions usually are extreme as to load, temperature range, high speed and the necessity for multiservice.

When extreme pressure performance of a grease is involved the requirements include

a. Good Structural Stability—worked and unworked under wet and dry conditions to resist leakage and washout.
b. Chemical Stability—to resist deterioration at high temperatures, up to 300F and to combat the action of mild acid or alkali contaminants.
c. Feedability and Pumpability—to enable satisfactory handling under prevailing temperature conditions. Here structure, apparent viscosity and consistency are influencing factors.
d. Rust Protection—to prevent corrosion of machine parts.
e. Compatibility with other greases.
f. Long-term Stability in storage, with minimum bleeding.
g. Long-term Service—including "Pack-for-Life" applications.

To a varied degree the grease under consideration must be studied as to the

(*Cont. on p. 340*)

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TECHNICAL DIGEST

(*Cont. from p. 339*)

extent to which these requirements relate to

a. Package Stability.
b. Performance in conventional dispensing equipment.
c. The range of service conditions which are likely to be encountered on the machinery for which the grease is intended.

One of the prominent advancements in extreme pressure grease research builds the EP components into the thickener rather than the oil, to obtain a calcium EP complex lead soap product which is regarded as wholly compatible not only with other additives but also with other greases with which it may be mixed in service. Proper balancing of the ingredients also favors maximum usable temperature up to 300F. (*Digested by A. F. Brewer*)

TESTS OF AIRCRAFT FLUIDS

(*Cont. from p. 327*)

indicate trends and focus attention to the fact that it is unwise to base acceptance of a fuel, fluid, or lubricant for a nuclear environment only on statically irradiated samples. These data further demonstrate the need for a more complete investigation of the relative effects of dynamic and static irradiation.

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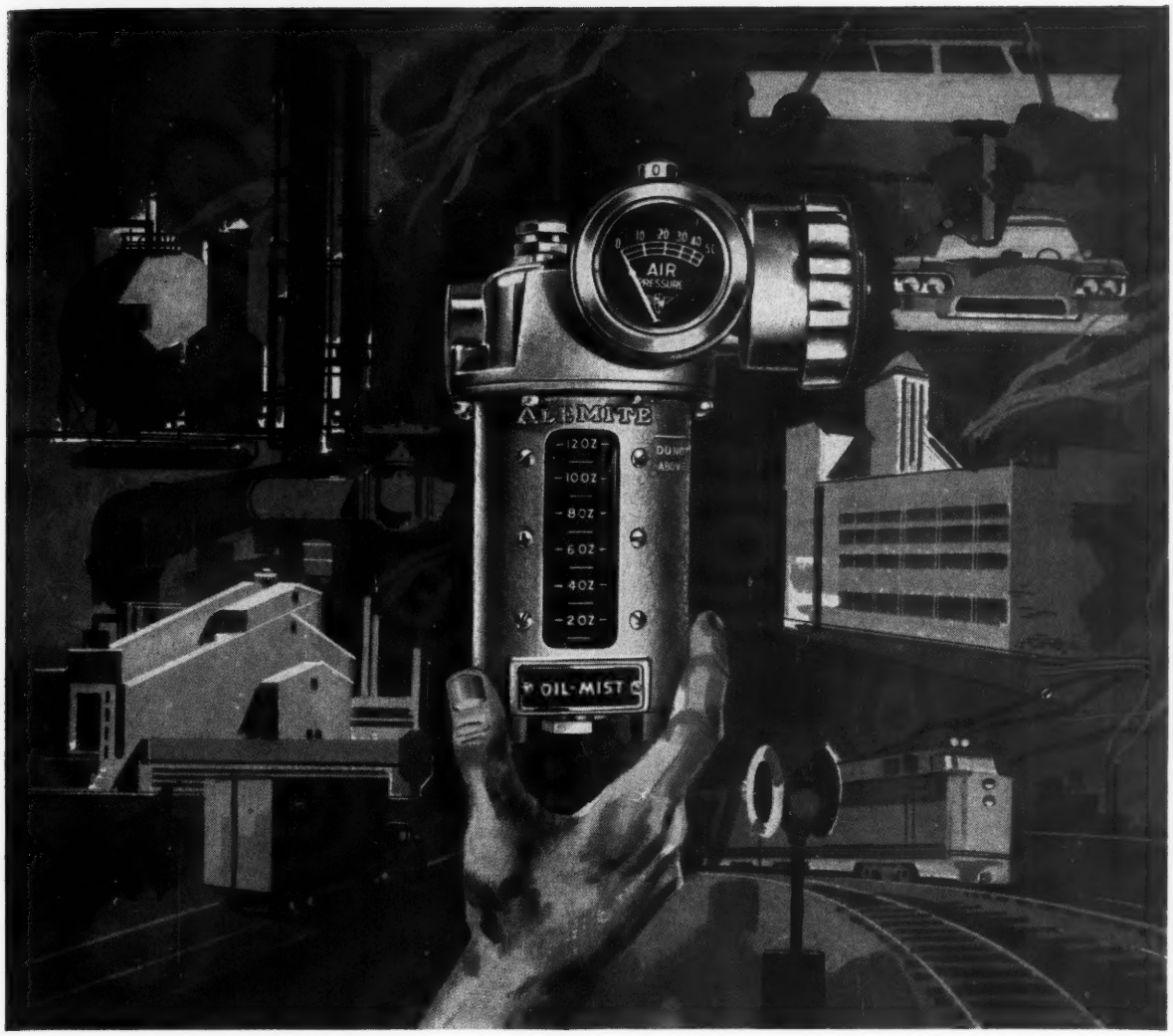

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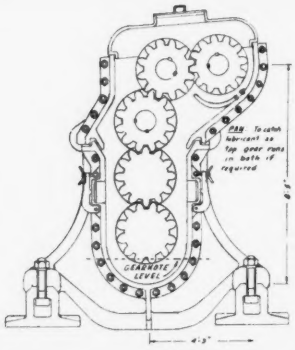

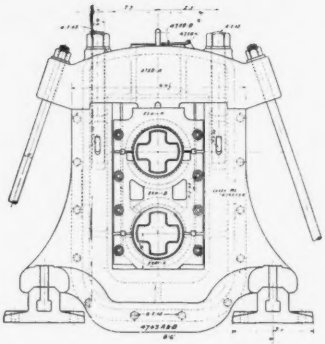

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